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From National Defense Stockpile (NDS) to Strategic Materials Security Program (SMSP): Evidence and Analytic Support

Volume I

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Executive Summary

In 1987, the U.S. Congress assigned the Secretary of Defense the job of determining requirements for and managing the National Defense Stockpile (NDS) of "strategic and critical" non-fuel materials (S&CMs).[1] Since then, the Institute for Defense Analyses (IDA) has provided regular analytic support to the Department of Defense (DOD) in structuring and implementing a stockpile requirements process.[2] IDA's support has included refining and helping to implement this analytic approach—in the transition from the Cold War to the current era of hybrid, asymmetric war—as well as conducting related special studies of specific materials such as jewel bearings, beryllium and, most recently, high-performance carbon fibers and rare earths.[3]

This paper summarizes IDA's latest analytic support to the DOD and the Defense National Stockpile Center (DNSC) in the NDS program area, including DOD's ongoing transition from an NDS to a Strategic Materials Security Program (SMSP).[4]

Three major and several smaller subtasks have been undertaken in the work reported here. First, IDA conducted a set of interim analyses employing the DOD's NDS/SMSP requirements process that the DOD can use during 2010 concerning plausible stockpiling

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1 Materials needed to produce essential defense and civilian products that could be in short supply in a plausible national security emergency. Current NDS inventories total about $1.225 billion (See Table 1-2 for details.)

2 The DOD's NDS/SMSP (National Defense Stockpile/Strategic Materials Security Program) requirements process has three major steps. The first two steps aim at building estimates of the time-phased, essential U.S. defense and civilian sector demands for major non-fuel strategic and critical materials (S&CMs) in the context of a mandated planning scenario. The third step involves both estimating the time-phased supply of these materials in that scenario (not counting any NDS inventories) as well as comparing those non-NDS supplies with the time-phased demands. If any gaps ("shortfalls") are identified, then existing NDS inventories are considered. If existing NDS inventories of a material are insufficient to cover (eliminate) the shortfall, then a shortage for that material is said to exist in the NDS. If the NDS inventory for that material suffices to cover the shortfall, there is no shortage. If inventories exceed shortfalls, such an overage is considered to be a "surplus."

3 See IDA papers P-2314, P-2716, P-2880, P-2885, P-2867, P-2900, P- 2953, and P-3680. Also see DOD's *Report(s) to the Congress on National Defense Stockpile Requirements 1989-2005*. See, as well, Appendices B and C of DOD's *Reconfiguration of the National Defense Stockpile Report to Congress, April 2009*.

4 The SMSP is described in DOD's *Reconfiguration of the NDS Report to Congress,* April 2009. Key elements of the SMSP include assessing a broader range of scenarios and additional materials, as well as assessing the merits and costs of risk-management/mitigation approaches in addition to traditional NDS-type stockpiling.

and other risk mitigation requirements. Second, IDA prepared key data for a regular set of materials (fifty-one “standard” and “specialty” materials) that will be analyzed later this year within the NDS/SMSP requirements process in order to inform the Secretary of Defense’s next full *NDS/SMSP Requirements Report to Congress* (due in January 2011). Third, IDA collected specific demand and supply data on a set of seventeen additional “new” materials of interest to the DOD. At a smaller level of effort, IDA has considered potential purchasing efficiencies that the DOD might attain in the materials markets, and also has developed several recommendations in order to help the DOD transition from an NDS program to an SMSP. The current study has been conducted over the nine-month period beginning in August of 2009 and ending in June of 2010.

Interim Base Case Assessments

The Interim Base Case (referred to as IBC1) represents a specific interim base case for NDS, founded on DOD planning assumptions, and employed by IDA to prepare a set of estimates of potential shortfalls for fifty-one sponsor-designated materials. These interim (2010) assessments of the fifty-one regular materials are based chiefly upon data and scenario parameters collected and compiled by IDA for the DOD in a recent analytic support cycle (2008-early 2009). These parameters include a revised—and more cautious—set of assumptions that the DOD selected in September 2009 regarding how quickly the United States and its key foreign suppliers can plausibly ramp up production of these materials in the scenario. They also include more cautious assumptions about the likely availability of materials from countries that are assumed to be hostile in the first year of the congressionally-mandated four-year planning scenario. Notable Interim Base Case (IBC1) assessments reported here—detailed in Chapter One—are that 40 percent (twenty-one) of the fifty-one materials manifest “shortfalls.” These shortfalls are valued at about $2.785 billion at recent market prices.[5] Existing NDS inventories do not completely cover these shortfalls. Only three of the twenty-one materials have enough NDS inventory to cover their respective IBC1 shortfalls.[6] Eighteen of these materials are therefore said to have shortages in IBC1.These eighteen shortages are valued at approximately $2.598 billion. Thus, existing NDS inventories (valued at $1.225 billion in total) cover only $0.187 billion of the shortfalls. Other NDS inventories ($1.038 billion) are holdings of materials either showing no shortfalls in IBC1 or that are surplus to any

5 If a “shortfall” of quantity X (say X tons) for material A is estimated in the scenario (that is, time-phased demands exceed time-phased non-stockpile supplies), then X is compared to any NDS inventory (I) of that material. If X exceeds I, a “shortage” is said to exist. If X is less than I, a “surplus” is said to exist. For further clarification, see footnote 2 above as well as Chapter 1of this report.

6 An additional six materials have some inventory, but not enough to cover the shortfall.

estimated shortfalls for materials. The following table provides a summary. With regard to IBC1, current NDS holdings are thus both inadequate and imbalanced.[7]

Shortfalls, Inventories and Shortages/Surpluses for 51 Regular Materials (2010 Interim Base Case)

	Shortfalls	Inventories	Shortages	Surplus Inventory
Of 51 Regular Materials, number with	21	15	18	9
Value ($ billion)	2.785	1.225	2.598	1.038

Of the seventeen "new" materials that the DOD also tasked IDA to compile data on in this task, four are rare earths, a tasking likely stimulated—in the case of the rare earths—by the substantial, and growing, dependence of the DOD upon the People's Republic of China (PRC) for key products that depend upon those materials. Interim Base Case (IBC1) assessments of these seventeen new materials —which are provided in Chapter Three—show shortfalls for five of them, including all of the rare earths we studied.

Purchasing Efficiencies

The DOD is interested in finding explicit ways to reduce its procurement costs, and the costs of strategic and critical materials are no exception. Such reductions may be achieved in several ways. IDA's initial ideas, findings, and recommended next steps are reported in Chapter Four of this paper. Highlights are as follows:

- Exploring a larger role for DNSC in the procurement of materials for defense production makes sense to IDA for several reasons:
  - — DNSC has buying expertise that many program offices may not have.
  - — DNSC can negotiate on behalf of multiple programs and thus increase the size of material buys, which should lead to better terms from the material vendor.

7 Shortfalls for the fifty-one materials total $2.785 billion (twenty-one materials have shortfalls). Total NDS inventories of $1.225 billion cover only $0.187 billion of that $2.785 billion, leaving shortages of $2.598 billion. Remaining inventories of $1.038 billion are thus surplus or excess.

  - — DNSC might also be in a position to play a "shock absorber" or clearinghouse role, balancing unexpected changes in requirements across individual procurement programs.

- Key unknowns include how much better DNSC-negotiated terms would be and what requirement quantities the programs would offer for DNSC negotiations.
- Continued DNSC experimentation probably will be needed to resolve these questions.

From NDS to SMSP—Several Recommendations

Based on this work, IDA recommends—in Chapter Six—that the DOD consider conducting several additional assessments as it designs and implements its new, and significantly reconfigured, NDS program, now called the Strategic Materials Security Program (SMSP). Assessments could include:

1. Exploring and tracking more systematically a wider range of plausible scenarios than the NDS normally considers;
2. Studying more materials (such as more rare earths);
3. More in-depth analyses of weapon-specific supply-chains;
4. Risk analyses of the likelihood and operational- as well as national-level consequences of various NDS/SMSP planning cases;
5. Analyses of the risk-mitigation effects and costs of various pre-crisis, contingency "surge" contract arrangements with U.S. and closely-allied vendors;
6. Regular form and grade studies of various "rolling inventory" strategies (inventories of materials subsidized to be held at and used (rolled over) by DOD contractors as they produce weapons);
7. Analyses of ways to incentivize private industry to revitalize supply-chains, e.g., through loan guarantees and multi-year contracts to buy their output;
8. Studies of material substitution strategies in the DOD and the civilian sector;
9. Analyses of ways to promote purchasing efficiencies for the DOD and the U.S. Government (USG) in the S&C materials area generally using DNSC's contracting expertise.

Structure of this Paper

This paper is organized in two volumes. Volume I, which is unclassified, has six chapters and several appendices.

Chapter One describes the Interim Base Case assessments for the fifty-one standard and specialty materials that the sponsor has asked IDA to conduct in this study.

Chapter Two provides an unclassified summary of the major data elements that IDA has assembled for the DOD's upcoming 2011 *NDS/SMSP Requirements Report* analyses.

Chapter Three first describes seventeen "new" materials for which IDA has also compiled preliminary data for the 2011 requirements study, and then summarizes the results of an Interim Base Case analysis of those materials as well.

Chapter Four offers IDA's initial ideas regarding opportunities that DNSC in particular may have to achieve purchasing efficiencies through skillful S&CM contracting for the DOD as a whole.

Chapter Five outlines initial findings concerning a recent material production and availability problem that confronted the DOD, highlights what the DOD did about it to address the problem and mitigate operational effects, and then offers several suggestions for strengthening the DOD's understanding of such matters in the future.

Chapter Six first describes several types of potential analyses within the DOD/NDS requirements framework that could help the DOD evaluate the effects on possible material shortfalls of various demand-side and supply-side risk mitigation options. Some of these assessments could be conducted as excursions and sensitivity analyses for the *2011 NDS/SMSP Requirements Report to Congress*. Chapter Six concludes with a broader set of recommendations for next steps the DOD may want to consider in transitioning from an NDS program to an SMSP.

Several appendices to Volume I provide supplementary information for the reader's convenience.

Volume II of this paper provides classified material pertaining to the study. In particular, information on the Quadrennial Defense Review (QDR) 2010 conflict scenarios and on the attrition and consumption data for those scenarios is presented in Chapters Two and Three of Volume II respectively. A summary of the reconstruction demands for a postulated attack on the U.S. homeland is provided in Chapter Four.

Contents

Appendices

1. Interim Base Case Assessments

This chapter describes the Interim Base Case (IBC1) assessments for the fifty-one standard and specialty materials that the sponsor has asked IDA to conduct in this study.

A. Interim Assessments with a Three-Step Requirements Process

The National Defense Stockpile (NDS) is designed to provide a federal stockpile of strategic and critical materials (S&CMs) adequate to hedge against the dangers of shortfalls of regular supplies of such materials for essential defense and civilian needs in the context of a major national security emergency (NSE). Identifying what shortfalls might plausibly arise, for which S&CMs, in the context of such an NSE, is the goal of a three-step *NDS requirements process* that IDA has helped DOD design. DOD has adopted and employs this process in the requirements analysis process by which the department determines the NDS goals, or stockpile requirements, it will recommend to the Congress in the regular *NDS Requirements Report* it must submit under the law. The law specifies that the scenario to be used for such estimation will be a four-year case, with a first year of significant conflict (consistent with regular DOD planning scenarios) followed by three years of regeneration of combat losses and key consumables used in the conflicts. The law indicates that all essential defense and civilian demands for relevant S&CMs during this scenario are to be provided for through such a process.

The first two steps of this NDS requirements process involve estimating time-phased essential defense and civilian demands for a specified set of S&CMs, in the context of the DOD designated scenario. In the third step, the time-phased supplies of these S&CMs judged likely to be available in the scenario—from each U.S. and foreign source (but not counting existing NDS inventories)—are estimated, and compared, period by period, against the essential demands for these S&CMs. If any gaps (“shortfalls”) are found in this time-phased demand-supply comparison, these are identified as candidate inventory goals (“requirements”) for the NDS.

Figure 1-1 depicts the three-step process.

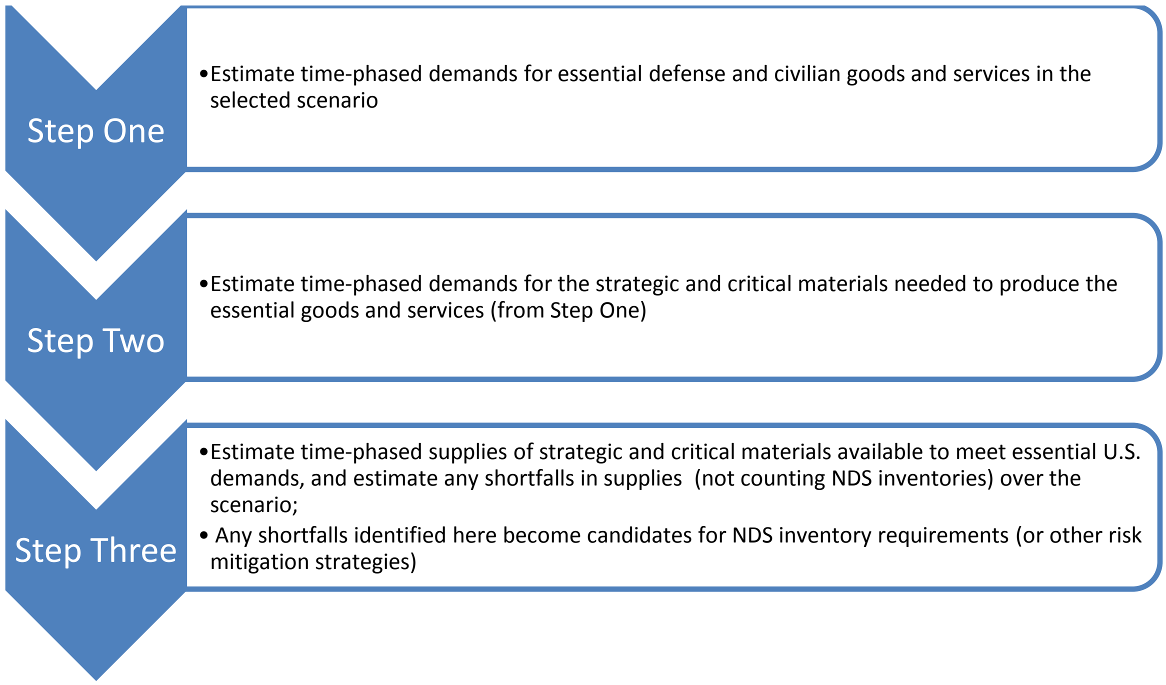

Figure 1-1. A Three-step NDS Requirements Process

In order to utilize this three-step process, a significant amount of data is needed and a number of important policy and strategy judgments must be made. These data and judgments are integrated and compiled for use in a suite of inter-related models in order to provide specific estimates—material-by-material—of both the physical quantities of any shortfalls that might plausibly arise in the case being assessed, as well as estimates of the approximate dollar value of any such shortfalls.

B. Major Assumptions for Interim Base Case Assessments

In the current study, IDA was commissioned first to prepare a set of estimates of the potential shortfalls that could arise for fifty-one sponsor-designated materials in the context of a specific Interim Base Case—a case which will be designated as IBC1 in what follows. In September 2009, a DOD Advisory Committee[1] designated the major planning assumptions for IBC1. These major assumptions are specified in Figure 1-2. (Please see the example calculation following Figure 1-2 for definitions of some terms in the figure.)

[1] This committee was led by OUSD (AT&L), with participation by OSD (CAPE), the Joint Staff (J-5), and DNSC.

	Assumption Category	IBC1 Value	Comment/Detail
Scenario Years		2008-11	
Essential Demands			
	Conflict Defense Demand	Replace lost/expended items in Postulated Conflicts	CC-2, CC-3, and several smaller conflicts (see Vol II)
	Other Defense Demand	Purchase Regular FYDP	
	Civilian Demand	CEA GDP forecast modified using "Essential Civilian Planning Factors"—Standard Values	See Appendix B for Details
	Homeland Recovery Demand	Rebuild damaged U.S. infrastructure after attacks	A nuclear attack on a major U.S. city
Available Supply			
	Production Ramp-Up Period in U.S.	One year to achieve full (3-shift) production levels	
	Production Ramp-Up Period in Foreign Countries	One year to achieve full (3-shift) production levels	
	Usable Foreign Production (UFP) available to the U.S.	U.S. Market Share (MS) of Country N's Production (XP) decremented also by DIA's country reliability factors (IA and RF), war-damage (WD), and shipping losses (SL)	UFP= XP*MS*IA*RF*WD*SL (Please see example below for definitions of key variables)
	Market Share (MS) of Foreign Production Available to U.S.	U.S.'s GDP-based "market share" (MS) of a country's "available production"	U.S. Market Share = (U.S. GDP)/(U.S. + scenario adjusted GDPs of "material demanders") (MS recognizes that other countries have reasonable demands too; U.S. cannot assume it will be able to buy all the world's S&CM output)[2]
	Other limits on U.S. Defense Sector's ability to use another country's supply	No use of foreign supplies if supplier is a "market dominator" (produces more than 50% of global supply)	Note: in IBC1, Canada and Australia are trusted for defense sector needs even if they are dominators
	Availability of Enemy Combatant production for U.S	None in first year; determined by market share, availability and dominator factors in 2nd-4th years	

Figure 1-2. Major 2010 Interim Base Case (IBC1) Assumptions

[2] The market share varies by material, but not country. (The market share computation for a material depends on the set of countries that demand the material.) The other decrement factors (IA, RF, WD, and SL) vary by country, but not material.

1. An Example

An example may help illustrate how the NDS requirements model determines the supplies of a given material that would be available to meet essential U.S. needs in a given year of the scenario. Assume that country N produces 100 units of material A. In IBC1, scenario year 1, the United States is estimated to be able to obtain from country N a fraction of that 100 units equal to the "U.S. Market Share" (MS) times a "War Damage to country N factor" (WD) times country N's "infrastructure availability factor" (IA) times country N's "pro-U.S. reliability factor" (RF) times a "shipping loss factor" (SL). Let us further assume that those variables have the following values in this example:

U.S. MS = .30 (equals an estimate of the share of country N's production of the material that the United States could reasonably expect to buy—without creating significant bidding wars—unless other constraints also apply, such as WD, IA, RF and SL)

WD =1.0 (1.0 = no war damage to Country N)

IA = 1.0 (1.0 = no other infrastructure degradation to Country N—aside from any WD)

RF = .8 (1.0 = Country N is completely willing to sell the U.S its normal market share)

SL = 1.0 (1.0 = no expected shipping losses of the material en route to the United States from country N)

Under these circumstances, the United States is estimated to be able to obtain the following amount of usable foreign production (UFP) of material A from country N in year 1:

UFP=100*MS*WD*IA*RF*SL, and with the values assumed above,

UFP =100*.3*1.0*1.0*.8*1.0 = 24 units of material A.

This same type of calculation is performed for all potential foreign suppliers, by country, material, and year of the scenario. The sum of all these foreign supplies (for a material in a given year) is estimated to be available/usable—with one major qualification—to meet essential U.S. demands in that scenario year. The qualification is that most global market "dominators" (those that supply more than 50 percent of global production of a material) were deemed by DOD in IBC1 to be unavailable to meet defense demands in the scenario, although they are assumed to be able to serve essential U.S. civilian demands. (Note, though, that Australia and Canada, even if they are "dominators," were deemed trustworthy enough by DOD to meet defense demands—as

well as civilian demands.) Finally, all U.S. production is assumed available to meet all essential U.S. demands (defense and civilian) in that year.[3]

2. Fifty-one Materials Assessed in IBC1, Shortfalls, NDS Inventories, and Shortages

The fifty-one sponsor-designated materials are shown in Table 1-1, along with the results of the shortfall assessments for IBC1. Table 1-1 indicates that twenty-one of these fifty-one materials have shortfalls totaling \$2.785 billion in the context of IBC1. Materials manifesting shortfalls are shown in bold. The shortfalls for six of these materials (antimony, columbium, tantalum, tin, rhodium and ruthenium) represent the overwhelming preponderance (79 percent)—in dollar value—of the total shortfalls in IBC1.

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[3] The basic supply-side algorithm is depicted in the example. Note that if more than enough supplies are available in the first year, they may be carried forward to meet subsequent year demands as well. New UFP and U.S. production also become available in subsequent years of the scenario. But this is a time-phased model, so later year supplies may not be used to meet prior year demands.

Table 1-1. Interim Base Case 1 Shortfalls for Materials Examined in the 2010 NDS Study[a]

Material Name	Units	Interim Base Case 1 Shortfalls	
		in units	in $M[b]
Standard Materials			
Aluminum Metal	ST	0	$0.00M
Aluminum Oxide, Fused Crude	ST	**69,656**	**$47.08M**
Antimony	ST	**27,828**	**$155.41M**
Bauxite, Metal Grade, Jamaica & Suriname	LDT	0	$0.00M
Bauxite, Refractory	LCT	**112,090**	**$48.29M**
Bismuth	LB	**4,446,190**	**$65.09M**
Cadmium	LB	0	$0.00M
Chromite, Chemical, Refractory, & Metallurgical Grade Ore	SDT	0	$0.00M
Chromium, Ferro	ST	0	$0.00M
Chromium Metal	ST	**2,490**	**$13.10M**
Cobalt	LB Co	**4,155,082**	**$95.11M**
Columbium	LB Cb	**6,742,435**	**$139.97M**
Copper	ST	0	$0.00M
Fluorspar, Acid Grade	SDT	**315,314**	**$32.50M**
Fluorspar, Metallurgical Grade	SDT	0	$0.00M
Iridium (Platinum Group)	Tr Oz	0	$0.00M
Lead	ST	0	$0.00M
Manganese Dioxide, Battery Grade, Natural	SDT	0	$0.00M
Manganese Dioxide, Battery Grade, Synthetic	SDT	0	$0.00M
Manganese, Ferro	ST	0	$0.00M
Manganese Metal, Electrolytic	ST	**15,303**	**$59.58M**
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M
Mercury	FL	0	$0.00M
Molybdenum	LB	0	$0.00M
Nickel	ST	0	$0.00M
Palladium (Platinum Group)	Tr Oz	0	$0.00M
Platinum (Platinum Group)	Tr Oz	0	$0.00M
Rubber (natural)	LT	0	$0.00M
Silicon Carbide	ST	**10,321**	**$20.88M**
Silver	Tr Oz	0	$0.00M
Tantalum	LB Ta	**5,023,544**	**$202.65M**
Tin	MT	**22,244**	**$246.92M**
Titanium Sponge	ST	0	$0.00M
Tungsten	LB W	**13,689,121**	**$91.65M**
Vanadium	ST V	0	$0.00M
Zinc	ST	0	$0.00M
Shortfall Subtotal: Standard Materials			**$1,218.22M**

Table 1-1. Interim Base Case 1 Shortfalls for Materials Examined in the 2010 NDS Study[a] (continued)

Material Name	Units	Interim Base Case 1 Shortfalls	
		in units	in $M[b]
Specialty Materials			
Beryllium Metal	ST	**36**	**$5.96M**
Beryllium Copper Master Alloy	ST	0	$0.00M
Beryl Ore	ST	**70**	**$0.01M**
Boron	MT	0	$0.00M
Gallium	KG	**308**	**$0.17M**
Germanium	KG	**30,399**	**$30.34M**
Hafnium	MT	0	$0.00M
Indium	Tr Oz	0	$0.00M
Rhenium	LB	**32,753**	**$58.24M**
Rhodium (Platinum Group)	Tr Oz	**93,690**	**$880.69M**
Ruthenium (Platinum Group)	Tr Oz	**1,375,348**	**$584.52M**
Tellurium	MT	0	$0.00M
Yttrium	MT Y_2O_3	**673**	**$7.07M**
Zirconium Metal	ST	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M
Shortfall Subtotal: Specialty Materials			**$1,566.99M**
Shortfall Total: All 51 Materials			**$2,785.21M**

a. Materials with shortfalls are shown in **bold**.

b. In millions of September 30, 2009 dollars. Dollar valuations for materials with inventory in the stockpile represent "realizable stockpile values" as of September 30, 2009, and might be higher or lower than the current market value.

Table 1-2 next depicts the inventories, if any, that are now held at NDS stockpiling sites around the country of these fifty-one materials. The NDS has inventories for fifteen of these materials, valued at $1.225 billion.[4] Inventories of just three of these fifteen materials (ferrochromium, ferromanganese and tungsten) comprise almost 90 percent of the total dollar value of current NDS holdings.

4 Fifteen materials show quantities of inventory (see inventory "in units" column), though only thirteen are estimated to have any significant market value.

Table 1-2. NDS Inventories, September 30, 2009

Material Name	Units	NDS Inventory, Sept. 30, 2009	
		in units	in $M[a]
Standard Materials			
Aluminum Metal	ST	0	$0.00M
Aluminum Oxide, Fused Crude	ST	0	$0.00M
Antimony	ST	0	$0.00M
Bauxite, Metal Grade, Jamaica & Suriname	LDT	0	$0.00M
Bauxite, Refractory	LCT	0	$0.00M
Bismuth	LB	0	$0.00M
Cadmium	LB	0	$0.00M
Chromite, Chemical, Refractory, & Metallurgical Grade Ore	SDT	0	$0.00M
Chromium, Ferro	ST	190,127	$264.20M
Chromium Metal	ST	5,180	$27.25M
Cobalt	LB Co	671,184	$15.36M
Columbium	LB Cb	22,156	$0.46M
Copper	ST	0	$0.00M
Fluorspar, Acid Grade	SDT	0	$0.00M
Fluorspar, Metallurgical Grade	SDT	0	$0.00M
Iridium (Platinum Group)	Tr Oz	568	$0.18M
Lead	ST	0	$0.00M
Manganese Dioxide, Battery Grade, Natural	SDT	0	$0.00M
Manganese Dioxide, Battery Grade, Synthetic	SDT	0	$0.00M
Manganese, Ferro	ST	444,046	$510.85M
Manganese Metal, Electrolytic	ST	0	$0.00M
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M
Mercury[b]	FL	112,353	$0.00M
Molybdenum	LB	0	$0.00M
Nickel	ST	0	$0.00M
Palladium (Platinum Group)	Tr Oz	0	$0.00M
Platinum (Platinum Group)	Tr Oz	8,380	$10.03M
Rubber (natural)	LT	0	$0.00M
Silicon Carbide	ST	0	$0.00M
Silver	Tr Oz	0	$0.00M
Tantalum	LB Ta	3,802	$0.15M
Tin	MT	3,956	$43.91M
Titanium Sponge	ST	0	$0.00M
Tungsten	LB W	43,704,092	$292.59M
Vanadium	ST V	0	$0.00M
Zinc	ST	8,255	$16.71M
Subtotal: Standard Materials			**$1,181.70M**

Table 1-2. NDS Inventories, September 30, 2009 (continued)

Material Name	Units	NDS Inventory, Sept. 30, 2009	
		in units	in $M[a]
Specialty Materials			
Beryllium Metal[c]	ST	164	$26.96M
Beryllium Copper Master Alloy	ST	0	$0.00M
Beryl Ore[d]	ST	1	$0.00M
Boron	MT	0	$0.00M
Gallium	KG	0	$0.00M
Germanium	KG	16,365	$16.33M
Hafnium	MT	0	$0.00M
Indium	Tr Oz	0	$0.00M
Rhenium	LB	0	$0.00M
Rhodium (Platinum Group)	Tr Oz	0	$0.00M
Ruthenium (Platinum Group)	Tr Oz	0	$0.00M
Tellurium	MT	0	$0.00M
Yttrium	MT Y_2O_3	0	$0.00M
Zirconium Metal	ST	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M
Subtotal: Specialty Materials			**$43.29M**
Total: All 51 Materials			**$1,224.99M**

a. In millions of September 30, 2009 dollars. Dollar valuations represent "realizable stockpile values" as of September 30, 2009, and might be higher or lower than the current market value. In general, NDS commodities are subject to substantial price fluctuations depending on changing market conditions.

b. Mercury. This report projects that the realizable stockpile value of the NDS mercury inventory is zero, although other parties continue to trade in this commodity.

c. Beryllium metal. The inventory (and dollar valuation) shown encompasses 18 short tons of vacuum-cast metal plus 146 short tons of hot-pressed powder (HPP) metal.

d. Dollar valuation of beryl ore inventory is zero to two decimal places.

Table 1-3 now shows the NDS shortages and surpluses of these materials that are manifest in the context of IBC1.

Table 1-3. NDS Shortages and Surpluses in Context of IBC1, September 2009[a]

Material Name	Units	NDS Inventory minus Shortfall	
		in Units	in $M[b]
Standard Materials			
Aluminum Metal	ST	0	$0.00M
Aluminum Oxide, Fused Crude	ST	(69,656)	($47.08M)
Antimony	ST	(27,828)	($155.41M)
Bauxite, Metal Grade, Jamaica & Suriname	LDT	0	$0.00M
Bauxite, Refractory	LCT	(112,090)	($48.29M)
Bismuth	LB	(4,446,190)	($65.09M)
Cadmium	LB	0	$0.00M
Chromite, Chemical, Refractory, & Metallurgical Grade Ore	SDT	0	$0.00M
Chromium, Ferro	ST	190,126	$264.20M
Chromium Metal	ST	2,690	$14.15M
Cobalt	LB Co	(3,483,898)	($79.75M)
Columbium	LB Cb	(6,720,279)	($139.51M)
Copper	ST	0	$0.00M
Fluorspar, Acid Grade	SDT	(315,314)	($32.50M)
Fluorspar, Metallurgical Grade	SDT	0	$0.00M
Iridium (Platinum Group)	Tr Oz	568	$0.18M
Lead	ST	0	$0.00M
Manganese Dioxide, Battery Grade, Natural	SDT	0	$0.00M
Manganese Dioxide, Battery Grade, Synthetic	SDT	0	$0.00M
Manganese, Ferro	ST	444,046	$510.85M
Manganese Metal, Electrolytic	ST	(15,303)	($59.58M)
Manganese Ore, Chemical & Metallurgical Grades	SDT	0	$0.00M
Mercury	FL	112,353	$0.00M
Molybdenum	LB	0	$0.00M
Nickel	ST	0	$0.00M
Palladium (Platinum Group)	Tr Oz	0	$0.00M
Platinum (Platinum Group)	Tr Oz	8,380	$10.03M
Rubber (natural)	LT	0	$0.00M
Silicon Carbide	ST	(10,321)	($20.88M)
Silver	Tr Oz	0	$0.00M
Tantalum	LB Ta	(5,019,742)	($202.50M)
Tin	MT	(18,288)	($203.00M)
Titanium Sponge	ST	0	$0.00M
Tungsten	LB W	30,014,971	$200.94M
Vanadium	ST V	0	$0.00M
Zinc	ST	8,255	$16.71M
Inventory Shortage Subtotal: Standard Materials			**($1,053.59M)**

Table 1-3. NDS Shortages and Surpluses in Context of IBC1, September 2009[a] (Continued)

Material Name	Units	NDS Inventory minus Shortfall	
		in Units	in $M[b]
Specialty Materials			
Beryllium Metal	ST	128	$21.00M
Beryllium Copper Master Alloy	ST	0	$0.00M
Beryl Ore[c]	ST	(69)	($0.00M)
Boron	MT	0	$0.00M
Gallium	KG	(308)	($0.17M)
Germanium	KG	(14,034)	($14.00M)
Hafnium	MT	0	$0.00M
Indium	Tr Oz	0	$0.00M
Rhenium	LB	(32,753)	($58.24M)
Rhodium (Platinum Group)	Tr Oz	(93,690)	($880.69M)
Ruthenium (Platinum Group)	Tr Oz	(1,375,348)	($584.52M)
Tellurium	MT	0	$0.00M
Yttrium	MT Y_2O_3	(673)	($7.07M)
Zirconium Metal	ST	0	$0.00M
Zirconium Ores and Concentrates	SDT	0	$0.00M
Inventory Shortage Subtotal: Specialty Materials			**($1,544.69M)**
Inventory Shortage Total: All 51 Materials			**($2,598.28M)**

a. For materials where NDS inventory is insufficient to cover the shortfall, the net shortage is shown in parentheses. The sum of these net shortages appears at the bottom of Table 1-3 ($2,598.28M).

b. In millions of September 30, 2009 dollars. Dollar valuations for materials with inventory in the stockpile represent "realizable stockpile values" as of September 30, 2009, and might be higher or lower than the current market value.

c. Dollar valuation of beryl ore shortage is zero to two decimal places.

Table 1-3 reveals that the existing inventories in the NDS are insufficient to make up for (cover) the shortfalls of the twenty-one materials manifesting such shortfalls in IBC1. The total shortage shown in Table 1-3 is valued at approximately $2.6 billion. The NDS also has surpluses of some of these fifty-one materials, surpluses valued at $1.0 billion. Even if these surplus inventories were completely sold off, and the proceeds used to buy more NDS inventories of those materials having shortages, significant shortages (of $1.6 billion) would still remain. Thus, under the assumptions of IBC1, the NDS inventories are inadequate to cover the estimated shortfalls.

C. Discussion of Interim Base Case (IBC) 1 Results

The 2005 NDS Base Case submitted by DOD to the Congress had much smaller shortfalls than those manifest in IBC1.[12] The principal reason for the larger shortfalls in IBC1 is that several underlying supply-side assumptions have been changed in the new case (IBC1). First, in the 2005 Base Case, DOD was willing to assume that U.S. and reliable foreign suppliers of these materials could move from current levels of production to full-scale, emergency operating levels in a matter of days or weeks. A review last fall by a DOD advisory panel suggested strongly that the 2005 Base Case assumption was unrealistic. As a result, IBC1 assumes—more cautiously—that it will take up to a full year for U.S. and reliable foreign suppliers to reach emergency operating levels.

Second, the 2005 NDS Base Case posited that production of materials by countries identified as enemy combatants/hostiles would become available to the United States starting six months into the Base Case scenario. The DOD Advisory Panel found this assumption to be overly optimistic as well. In particular, the panel viewed the possibility of persistent internal turmoil in the hostile countries to be too likely to warrant retaining the 2005 Base Case assumption. Accordingly, the IBC1 assumes instead that hostile countries' production will not be available for at least a year into the four-year scenario.

Changes in these two supply-side assumptions create a significant difference in the shortfalls manifest in IBC1 versus those in the 2005 NDS Base Case. To illustrate this point, IDA prepared an excursion from IBC1 which uses the 2005 Base Case assumptions for these two variables. The difference is striking. Only six of the fifty-one materials exhibit shortfalls under this excursion, totaling $846 million (IBC1 prices).

D. Toward a 2011 National Defense Stockpile (NDS) / Strategic Materials Security Program (SMSP) Base Case

As indicated, IBC1 is an Interim Base Case for the NDS. It will be replaced by a Base Case that will be selected by DOD and submitted in a new Requirements Report that is due to the Congress by January 15, 2011. Chapters Two and Three of this paper document the new data collection efforts that IDA has undertaken under the current study for use in preparing requirements estimates that DOD will most likely employ in its forthcoming *2011 NDS/SMSP Requirements Report to Congress*.

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[12] The 2005 NDS Base Case shortfalls totaled $185.63 million in IBC1 prices, and $157 million as reported in the *2005 Report to Congress on NDS Stockpile Requirements*.

2. New Data and Planning Factors for the 2011 Requirements Report

This chapter describes the major regular data types that have been collected by IDA in the current study for use in preparing Base Case and other estimates for the *2011 NDS/SMSP Requirements Report to Congress*.

A. Stock Piling Act Mandates a Specific Structure for the NDS/SMSP Base Case

For context, the Stock Piling Act, as amended, mandates that DOD will base its NDS/SMSP requirements recommendations upon a specific type of scenario, the main features of which are as follows:

> "The Secretary shall base the national emergency planning assumptions on a military conflict scenario consistent with the scenario used by the Secretary in budgeting and defense planning purposes. The assumptions to be set forth include assumptions relating to each of the following:
>
> (1) The length and intensity of the assumed military conflict.
>
> (2) The military force structure to be mobilized.
>
> (3) The losses anticipated from enemy action.
>
> (4) The military, industrial, and essential civilian requirements to support the national emergency.
>
> (5) The availability of supplies of strategic and critical materials from foreign sources during (a) the mobilization period, (b) the military conflict, and (c) the subsequent period of replenishment, taking into consideration possible shipping losses.
>
> (6) The domestic production of strategic and critical materials during the mobilization period, the military conflict, and the subsequent period of replenishment, taking into consideration possible shipping losses.
>
> (7) Civilian austerity measures required during the mobilization period and military conflict.

> The stockpile requirements shall be based on those strategic and critical materials necessary for the United States to replenish or replace, within three years of the end of the military conflict scenario required under subsection (b), all munitions, combat support items, and weapons systems that would be required after such a military conflict."[13]

B. Data and Planning Factors Needed to Conduct Three-step NDS Requirements Process

In order to conduct structured shortfall assessments within the context of a case such as this, a number of major data and planning factors are needed to "populate" the analytic models.[14]

The major categories of planning factors and data are depicted in Figure 2-1.

IDA has compiled these data and planning factors from a variety of sources for the 2011 Base Case. The remainder of this chapter provides a summary description of each of these major planning factors and data sets, in turn. A major source of the supply-side data has been the commodity specialists at the U.S. Geological Survey (USGS).

Scenario Dates: The sponsor has selected the years 2011-14 for the 2011 NDS/SMSP Base Case.

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[13] *The Strategic and Critical Materials Stock Piling Act of 1979*, "Biennial Report on Stockpile Requirements," U.S. Code 50 (2010), §98h-5.

[14] These models are documented in the following IDA papers: IDA P-2867, *The Stockpile Sizing Module*, IDA P-2953, *The FORCEMOB Model*. Appendix A of this report provides a brief overview of the models.

	Data Category	Proposed 2011 Base Case Elements	Comment/Detail	Source
Scenario Years		2011-2014	Sponsor decision	
Essential Demands				
	Conflict Scenario and Regeneration Demand	Replace attrited/used items in postulated conflicts	To be based on QDR2010 Cases 1-3	OSD(CAPE) JS (J8)
	Homeland Recovery Demand	Rebuild damaged U.S. infrastructure after attacks	Based on estimates of damage from attack on U.S. in QDR 2010 Cases	IDA estimates
	Regular Defense Demand	Purchase Regular FYDP	Feb 2010 FYDP Proposal for 2011-15	CEA, DOD
	Civilian Demand	CEA GDP forecast modified using "Essential Civilian Planning Factors"—Propose using standard factor values (see Appendix B)	Based on Council of Economic Advisors (CEA) forecast of Feb. 2010, modified by essential factors (INFORUM models)	CEA Civilian Advisory Group IDA estimates with INFORUM Models
	Material Demand Factors	Material Consumption Ratios (MCRs) Quantity of a material used/per $1B of output from an industry sector	Special studies conducted by DoC (standard materials)	DOC for standard materials USGS and industry sources for specialty materials
		Proxy MCRs	IDA proxy MCR method with data from USGS and corporations (specialty and "new" Materials)	Material regularly used in an industry sector times (ratio of scenario demand for output from sector to regular demand for output)—summed across all sectors
Basic Supply Data	U.S. and Foreign Production and Production Capacity		DoC, USGS, corporate data, International Rubber Study Group	

Figure 2-1. Major Data Elements for Shortfall Assessment Process

	Data Category	Proposed 2011 Base Case Elements	Comment/Detail	Source
Limits on U.S. supplies	U.S. Market Shares (MS)	U.S. GDP/(sum of all the material's demanders' GDPs)	CIA GDP estimates; USGS "demander country" data	Other countries have legitimate demands; U.S. cannot assume it can buy it all.
	War Damage Factors (WD)	Fraction of a country left undamaged	Estimates from OSD(CAPE); JS; IDA	
	Shipping Loss Factors (SL)	Fraction of shipping not lost	Estimates from OSD (CAPE); JS;IDA	
	Infrastructure Availability Factors (IA)	Fraction of a country that is stable in scenario	Estimates from DIA, other SMEs as available	
	Willingness to Sell to U.S. Reliability Factors (RF)	Fraction of U.S. market share (MS) that a country is willing to sell to U.S.	Estimates from DIA, other SMEs as available	
	Enemy combatant countries in conflict scenario	Supplies treated as unavailable during conflict	Enemies—as stipulated in QDR 2010 Cases 1-3	

Figure 2-1. Major Data Elements for Shortfall Assessment Process (Continued)

1. Demands for Essential Goods and Services

Conflict Scenarios: The 2010 QDR has produced a set of planning cases (Cases 1-3) that have been approved for use in the 2011 NDS Requirements estimation process. These classified cases are depicted in summary form in Volume II (classified) of this paper. Together, these cases feature attacks on the U.S. homeland, counter-terrorist, counter-insurgency, and stability operations in several theaters of operation, and multiple major combat operations.

Conflict Regeneration Demands: Conflict Attrition and Consumption Data: The planning cases mentioned above (Cases 1-3) have been examined for potential combat attrition and consumption of key munitions and other soldier support items. These classified data are depicted in Volume II of this paper.[15]

Homeland Recovery: The QDR planning cases postulate significant damage to the U.S. homeland, the result of a major attack on a U.S. city. Repair and reconstruction costs have been estimated by IDA for this damage, and are provided in Volume II of this paper.

Regular Military Demand: Estimates of the time-phased demands upon industrial sectors associated with the regular Future Years Defense Program (FYDP) are needed for the NDS requirements process, in order that the associated industry-sector demands for

[15] Defense Translator data: Conflict defense demands for weapon systems and consumables in the context of this scenario need to be "translated" into demands for outputs from specific industry sectors. The defense translator is a mapping device enabling that translation for numerous relevant weapon systems. The Defense Translator data have been obtained from OSD (Cost Analysis and Program Evaluation [CAPE]).

S&CMs to produce the FYDP may be estimated. These data have been compiled through estimates provided by the Council of Economic Advisors (CEA).

Essential Civilian Demand: The Stock Piling Act calls for consideration of all essential civilian demands for relevant S&CMs in the context of the planning scenario, but does not specify what "essential" means. DOD has elicited the advice of key civilian departments and agencies (a Civilian Advisory Group[16]) as to how much of what kinds of normal U.S. consumption and investment should be considered essential for purposes of the NDS Base Case for requirements planning. A set of "austerity" planning factors has been developed based upon this advice. They are provided in Appendix B of this paper. IDA applies these planning factors to a baseline CEA forecast of the U.S. economy for the relevant scenario years using an established macro-economic simulation model (LIFT/ILIAD).[17] A discussion of this approach, and of alternatives to it, is also provided in Appendix B.

Material Consumption Ratios (MCRs): Step Two of the three-step NDS requirements process translates time-phased essential demands for goods and services into time-phased demands for the S&CMs needed (in ordinary production processes) in order to generate those goods and services. At the heart of this second step is a data set of material consumption ratios (or "MCRs"). MCRs are estimates, industrial sector by industrial sector of the U.S. economy, of how much of a given S&CM (pounds of cobalt, for instance) is needed to produce a given amount of output ($1 billion of output) from each particular industrial sector. These MCR estimates are built from data compiled by the Department of Commerce (DOC)—under contract to the DNSC—and provided to IDA for use in the requirements process. Regular MCR data are available for thirty-six S&CMs. These thirty-six materials are those IDA refers to as "standard" materials (see Table 1-1, for example).

Proxy MCRs: Some S&CMs of interest to DOD have not had MCR studies conducted by DOC. For these materials, an alternate methodology is employed to estimate the demands for these materials that could arise in the context of a planning case. This alternate methodology is labeled a "proxy MCR" approach, for convenience. The proxy MCR approach is described in Appendix C of this paper. The proxy MCR approach requires the types of data shown in Table 2-1 for any particular material of interest.

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16 Members of the CAG normally include representatives from the following Federal departments and agencies: Agriculture, Commerce, Energy, Health and Human Services, Homeland Security, Housing and Urban Development, Interior, Labor, the Office of Management and Budget, State, Transportation, and Treasury.

17 A combination of two econometric models is used: LIFT (Long-term Inter-industry Forecasting Tool) and ILIAD (Inter-industry Large-scale Integrated and Dynamic model). These models were developed by the INFORUM group at the University of Maryland.

For the current study, IDA has compiled information of this kind for two sets of materials, the so-called fifteen specialty materials, which are listed in Table 1-1, and seventeen other, “new,” materials, which are described in Chapter Three.

Table 2-1. Proxy Material Consumption Ratio (MCR) Demand Variables

Proxy MCR Demand Variables	Detail on Demand Variable
1. Consumption	Total (civilian + military) U.S. consumption of the material for a recent year or years
2. Application areas	List of application areas the material is used in
3. Consumption by application	For each application area, the proportion of total U.S. consumption used in it
4. Map of application areas to industry sectors	For each application area, the industry sectors (4-digit NAICS) associated with that application
5. Price	Recent price

2. Supply Side Data for Materials

Basic supply information has been compiled for each material of concern in the study. The information includes estimated production and production capacity for the U.S. and for each foreign country that can produce the material, estimated for each year of the scenario period. These data have been obtained from the commodity specialists at USGS.

Factors Specifying Limits on U.S. Use of U.S. and Foreign Supplies of Materials

For the years of interest in the NDS planning case, the basic production information is modified to reflect estimates of likely limits on the availability to the United States of such supplies in the scenario. The following factors pertain here.

> **Market Share (MS):** The first of these limiting factors is called “market share,” or MS. MS refers to the fraction of a country’s production that is judged by DOD to be available for the United States to use in the scenario. That fraction is normally estimated as equal to the U.S. GDP as a share of the total GDPs of the countries (including the U.S.) that are known to use the material. The data for these estimates are compiled from Central Intelligence Agency (CIA) estimates of GDPs and USGS data on material “demanders” around the world.
>
> **Country Reliability Factors (IA and RF):** How able and willing individual countries will be to supply the United States with the U.S.

market share of that country's production in the context of the planning case is estimated by country experts within DOD, specifically by country experts at the Defense Intelligence Agency (DIA). These "country reliability" estimates are prepared by DIA in the context of the classified planning cases specified in Volume II of this paper. The first of these factors is called an Infrastructure Availability factor, or IA. The second factor is called a willingness to sell to the United States factor or Reliability Factor (RF) for short. Appendix D of this paper provides the key questions that are asked of the country reliability evaluators.

War Damage (WD): Damage caused by the process of warfare (e.g., bombing damage) to a country that is directly involved in the conflict scenario might affect the productive capacity of the country. In particular, it might affect the amounts of materials or industrial output the country can supply. The war damage factor models this concept. The factor value is between zero and one and represents the proportion of productive capacity that is *undamaged*. For example, if the factor value is 0.9, then the country can supply 90 percent of the material that it ordinarily would (other decrement factors might also be applied). The war damage factors are input to the modeling process. They vary by country, and can also vary by year of the scenario, in concordance with the recovery and regeneration of the country's productive capacity after the conflict.

Shipping Losses (SL): The modeling process allows supply from a foreign country to suffer attrition in transit (due, perhaps, to enemy attack on the maritime shipping), so that only a fraction of it reaches the United States. The shipping loss factor represents this fraction. The shipping loss factors are input to the modeling process, and can vary by supplier country and year of the scenario (e.g., to model greater losses in the conflict year). For example, if the shipping loss factor is 0.8, then 20 percent of the supply (from a given country in a given year) is lost due to attrition en route, and 80 percent reaches the United States (other decrement factors might also be applied).

Dominator Considerations: For those foreign countries' deemed able and willing to supply (sell) some fraction of their production to the United States in the context of the NDS planning case, there is an additional limit that may be placed upon the U.S. ability to use such supplies. In particular, if a foreign supplier is a particularly dominant supplier, the DOD advisory council may decide that it is too risky to count upon such a supplier, at least for defense needs, even if it is a very friendly and regular peacetime supplier. Such a dominator limit was invoked in the 2005 Base Case as

well as the IBC1 summarized in Chapter One. Note, though, that highly trusted countries (100 percent reliable, or "assured"), even if they are dominators, were assumed to be available to meet defense (and civilian) needs in IBC1.

Hostile Countries in the Conflict Scenario: Over the years, DOD has normally considered supply from hostile countries (i.e., enemy combatants) in the NDS Base Cases as simply being unavailable to the United States for a certain period of time. Although the model does not have an explicit input for this option, it can be implemented readily by adjusting the war damage (WD) factor. The length of time supply from enemy countries is zeroed out has been determined judgmentally by DOD. (IBC1 used a value of one year for this variable.)

C. Discussion and Summary

Almost all major data sets have now been compiled for the 2011 Requirements Report. One data set that IDA still needs is the DOC Survey of Plant Capacity. It should be available in June.

These updated data sets, once combined with key DOD decisions regarding Base Case demand and supply-side assumptions, will enable IDA to conduct the major assessments of Base Case shortfalls, shortages, and surpluses for the *2011 DOD NDS/SMSP Requirements Report*, due to Congress by January 15, 2011.

The last full *NDS Requirements Report to Congress*, submitted in 2005, provided assessments of fifty-three standard and specialty materials. The *2011 NDS Requirements Report* will be able to provide Congress assessments of fifty-one of those materials[18] as well as assessments of an additional set of materials that the sponsor has designated as a high priority for DOD to examine in the upcoming requirements cycle—if the data can be found for them. For convenience, these additional materials are labeled "New" in in this paper. They are considered "new" here because this is the first time they are being addressed in DOD's NDS requirements process. IDA will also refer to these additional materials as the "specialty II" set from time to time.

18 Two of the fifty-three (boron composite filaments and boron nitride) had very limited data available, and the sponsor believes that these two are not worth pursuing for the *2011 Requirements Report*.

3. "New" Materials

This chapter summarizes IDA's efforts to compile relevant data on a set of eighteen additional materials of high interest to the Department of Defense, materials beyond the standard and specialty materials described in earlier chapters of this paper. These are additional materials that DOD wants to examine systematically in the context of the 2011 NDS/SMSP Requirements Report to Congress.

These eighteen "new" materials were nominated by DNSC and the Office of the Secretary of Defense (OSD) for examination based on several considerations. Many of these eighteen materials were identified as problematic by the Military Services in a 2008 OSD survey.[19] The Services were surveyed by OSD in the summer of 2008 about the materials they or their principal contractors were having problems obtaining on a timely basis.

In addition, through earlier work for DNSC and OSD in 2008, IDA determined that while DOD is using several of the other materials on this list of eighteen to build its top-priority weapon systems, relatively little is known systematically about the adequacy of their supply in the context of the official NDS planning case. IDA was asked to nominate several of these materials for analysis in this NDS planning and assessment cycle, and IDA did so. Finally, OSD was asked to nominate any other materials that they deemed potentially problematic and important enough to assess in the NDS planning context. OSD proposed several additional materials.

The eighteen new materials that IDA has sought relevant data for in the current study are shown in Table 3-1, along with their principal characteristics and major applications.

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19 The results of that survey are summarized in Appendix C of DOD's April 2009 *Reconfiguration of the NDS Report to Congress*.

Table 3-1. "New Materials": Characteristics and Major Applications

"New" Material	Characteristics	Major Applications
Boron Carbide	B_4C is one of the hardest materials known, ranking third behind diamond and cubic boron nitride.	Abrasive, Chobham Armor, neutron absorber for nuclear power control. Semiconductors, high pressure cutting nozzles.
Europium	A highly reactive divalent rare earth metal that is stable as an oxide.	Nuclear control rods, Neutron absorber, laser phosphors, cathode ray tube (CRT) and flat panel displays.
Terbium	A silvery-white rare earth metal that is malleable, ductile, and soft enough to be cut with a knife.	Fuel Cells, Lasers, CRTs, Magnetorestrictive Alloys (naval sonar systems), thermoluminescent materials.
Neodymium	A bright, silver-colored rare-earth metal element, found in monazite and bastnaesite.	Magnets for motors, lasers (coherent light), Spectral Line calibration. Used for coloring glass and for doping some glass lasers. The metal is used in permanent magnets for the electric motors in hybrid cars and defense systems.
Samarium	A bright, silvery rare-earth metal element that is relatively stable in air but will ignite at $150^{o}C$.	Neutron absorber in nuclear reactors, doping agent for Lasers, permanent magnets with cobalt.
M50	A low-alloy, vacuum-melted, intermediate high speed, molybdenum type tool steel.	Vacuum-melted steel used in bearings and structural components of aircraft engines and missiles.
300M	A low-alloy, vacuum-melted, high-strength steel.	Aircraft landing gear, high-strength bolts, airframe parts.
Armor Steels	Two principal varieties of armor steel (Rolled Homogeneous Armor & High Hard Armor) used by DOD.	Armored vehicles.
S-2 Glass Fiber	S-2 Glass fiber is a silica-based fiber which was developed in the 1960s for military applications. Structural fiberglass is a high-strength, lightweight fiber with superior mechanical properties compared to traditional fiberglass (40-70 percent).	Military uses include composite structures in fixed and rotary wing aircraft, ground combat vehicles, and navy ships. Commercial uses include composite structures for aircraft, sporting goods and industrial uses.

Table 3-1. "New Materials": Characteristics and Major Applications (Continued)

"New" Material	Characteristics	Major Applications
High-purity Quartz Fiber	Quartz fiber is a high-purity silica fiber developed for aerospace and defense applications in the 1960s. Quartz fiber is a high-strength, lightweight fiber with exceptional electrical and thermal properties including low dielectric constant and high temperature resistance. It is commonly used as reinforcement for composite materials.	Military uses include composite structures for thermal protection and electromagnetic applications including heat shields, low observable aerostructures, radomes, and antenna windows. End-uses include manned and unmanned aircraft, missiles, and spacecraft. Commercial applications are limited but expanding for commercial aircraft radomes and satcom antenna windows.
Carbon Fibers: AS-4 IM-6 IM-7 T-300 T-700	Carbon fibers are most often made from a polyacrylonitrile (PAN) precursor. They were developed in the late 1950s and early 1960s in Japan, England and the U.S. There are numerous grades and forms of PAN-based carbon fibers. Some of the most common include standard modulus fiber (AS-4, T-300 and T-700). Intermediate modulus fibers are becoming increasing popular (IM-6 and IM-7). Carbon fibers are most known for their attractive mechanical properties (high-strength and stiffness).	Military uses include composite structures used in manned and unmanned fixed and rotary wing aircraft as well as tactical and strategic missiles, space launch vehicles, and satellites. Emergent applications include naval vessels and military ground vehicles. Commercial uses include numerous industrial applications such as machine rollers, windmill blades, and automobiles, as well as sporting goods, offshore marine structures, and commercial aircraft, space launch vehicles, and satellites.
Kevlar Fiber	Kevlar is a para-aramid synthetic fiber developed by DuPont in the mid 1960s for industrial applications. Para-aramid fibers have high tenacity and elastic modulus and possess exceptional ballistic properties.	Military uses include textiles for ballistic protection such as soft body armor, combat helmets, spall liners for military ground vehicle armor, and aircraft structures. Commercial uses include textiles for body armor for civilian law enforcement, automotive products, sheathing for cables, marine structures, and cordage.

Table 3-1. "New Materials": Charactertistics and Major Applications (Continued)

New" Material	Characteristics	Major Applications
Nomex Fiber	Nomex is a meta-aramid, synthetic fiber developed by DuPont in the early 1960s. Meta-aramid fibers have high flame and heat resistant properties.	Military uses include high-temperature and flame resistant textiles for garments worn by military aviators, ground combat vehicle crews, firefighters and other emergency responders. Commercial uses include high-temperature and flame resistant textiles for civilian firefighters and industrial safety apparel as well as insulation applications industrial equipment.
Lithium	Lithium, the alkali metal with the lowest atomic number, is lightweight and highly reactive.	Applications include ceramics and glass, batteries, lubricating greases, aluminum production processing, air treatment, continuous casting, chemical processing, and pharmaceuticals.

Explanatory Note: "high speed," when describing steel, means suitable for high speed cutting tool applications, which results from the high hardness and high abrasion resistance of the steel. "High strength" means able to support high tensile stresses before failing. The two properties are different. "Low alloy" steel means low carbon content (which is sometimes a desired property).

Major producers of these materials are shown in Table 3-2, along with the chief data sources for this study. The information that IDA has compiled—from a variety of sources—on these seventeen materials is similar to the data that IDA collects for the "specialty" materials described in Chapter Two. Data were obtained from the principal sources shown in Table 3-2.

IDA has been able to compile enough relevant information on seventeen of these materials to permit a preliminary analysis of them in the context of IBC. Adequate data on the other one (boron carbide) has proven elusive. Data on seventeen new materials have been used in preliminary tests to determine whether any of these materials manifest shortfalls in the IBC case described earlier in this paper (see Chapter One). Preliminary analysis of these seventeen materials in the context of IBC1 suggests that shortfalls would arise for five of them, and that several others manifest supply-to-demand ratios that are fairly close to shortfall status.

Table 3-2. Major Producers and Data Sources for New Materials

"New" Material	Major Producers	Major Data Sources for this Study
Europium	U.S.: none to very limited Other: Peoples' Republic of China (PRC) firms	USGS
Terbium	U.S.: none to very limited Other: Peoples' Republic of China (PRC) firms	USGS
Neodymium	U.S.: none to very limited Other: Peoples' Republic of China (PRC) firms	USGS
Samarium	U.S.: none to very limited Other: Peoples' Republic of China (PRC) firms	USGS
M50	U.S.: Latrobe Specialty Steels, Carpenter Technology Corp., and Allegheny Technologies, Inc. (ATI) Other: France, Austria, Taiwan.	DOD (OSD Supply Chain Working Group, U.S. Army Aviation and Missile Research Development and Engineering Center, Defense Contract Management Agency [DCMA]) and Latrobe Specialty Steels
300M	U.S.: Latrobe Specialty Steels, Carpenter Technology Corp., Universal Stainless & Alloy Products, Inc., and four other firms. Other: United Kingdom, France, Austria, and Taiwan	DOD (OSD Supply Chain Working Group, US Army Aviation and Missile Research Development and Engineering Center, DCMA) and Latrobe Specialty Steels
Armor Steels	U.S.: Arcellor-Mittal, Evraz Oregon Steel Mills, and Clifton Steel Other: Australia, Canada, Germany, and Sweden	DOD (U.S. Army Research, Development, and Engineering Command-Tank Automotive Research, Development and Engineering Center, DCMA)
S-2 Glass Fiber	U.S.: AGY, Inc. Other: None	Proprietary data from the company
High-purity Quartz Fiber	U.S.: Saint Gobain, (foreign U.S. subsidiary plant of French firm) Other: Saint Gobain company of France	Proprietary data from the company
AS-4 Carbon Fiber	U.S.: Hexcel Other: Hexcel foreign subsidiary plant in Spain	Proprietary data from the company
IM-6 Carbon Fiber	U.S.: Hexcel Other: None	Proprietary data from the company
IM-7 Carbon Fiber	U.S.: Hexcel Other: Hexcel foreign subsidiary plant in Spain	Proprietary data from the company
T-300 Carbon Fiber	U.S.: Cytec Engineered Materials. Other: Toray company of Japan with plants in Japan and France	Proprietary data from the company and other confidential industry sources

Table 3-2. Major Producers and Data Sources for New Materials (Continued)

"New" Material	Major Producers	Major Data Sources for this Study
T-700 Carbon Fiber	U.S.: Toray Carbon Fibers America (foreign U.S. subsidiary plant of Japanese firm). Other: Toray company of Japan with plants in Japan and France.	Proprietary data from the company
Kevlar Fiber	U.S.: DuPont Other: DuPont foreign subsidiary plant in Ireland	Proprietary data from the company
Nomex Fiber	U.S.: DuPont Other: DuPont foreign subsidiary plant in Spain	Proprietary data from the company
Lithium	U.S.: Chemetall Foote Other: Major foreign producing countries are Chile, Argentina, China	USGS, DoC

The results of the initial IBC1 assessment—for these seventeen "new" materials—are depicted in Table 3-3. The worst year supply-to-demand ratio is defined as follows. For each year of the scenario, the models compute the demand, the available supply, and the ratio of available supply to demand. One can then note the lowest such ratio.

Table 3-3. New Materials: Worst-Year Supply-to-Demand Ratios

New Material	Worst-Year Supply-to-Demand (S/D) Ratio In IBC1 Scenario
Europium	0
Terbium	0
Samarium	0
Neodymium	0
Specialty Steel—300M	1.73
Specialty Steel—Armor	1.46
Specialty Steel—M50	1.51
Carbon Fiber—AS-4	1.78
Carbon Fiber—IM-6	0.96
Carbon Fiber—IM-7	1.43
Carbon Fiber—T-300	1.73
Carbon Fiber—T-700	5.32
Kevlar	1.16
Lithium	3.49
Nomex	1.15
High-purity Quartz Fiber	Withheld
S-2 Glass Fiber	1.28

The following sections provide more detail with regard to each of the seventeen "new" materials for which IDA was able to gather initial data for requirements analyses.

A. Rare Earths and Lithium

Over the last five years, the United States has consumed—for final domestic use—on the order of 36,000 metric tons (MT) of rare earth oxides (REO), or about 7,200 MT per year, of which the DOD may use about 5 percent, or about 360 MT/yr.

The U.S. Geological Survey (USGS) *Mineral Commodity Summaries 2010* summarizes the rare earth situation for the United States in 2009 as follows:

> In 2009, rare earths were not mined in the United States; however, rare-earth concentrates previously produced at Mountain Pass, CA, were processed into lanthanum concentrate and didymium (75% neodymium, 25% praseodymium) products. Rare-earth concentrates, intermediate compounds, and individual oxides were available from stocks. The United States continued to be a major consumer, exporter, and importer of rare-earth products in 2009. The estimated value of refined rare earths imported by the United States in 2009 was $84 million, a decrease from $186 million imported in 2008. Based on final 2008 reported data, the estimated 2008 distribution of rare earths by end use, in decreasing order, was as follows: metallurgical applications and alloys, 29%; electronics, 18%; chemical catalysts, 14%; rare-earth phosphors for computer monitors, lighting, radar, televisions, and x-ray-intensifying film, 12%; automotive catalytic converters, 9%; glass polishing and ceramics, 6%; permanent magnets, 5%; petroleum refining catalysts, 4%; and other, 3%.

Proprietary-level information regarding the rare earths that DOD has tasked IDA to examine has been obtained and compiled from the USGS and is now ready for assessment in the *2011 Requirements Report to Congress*.

Shortfalls for the rare earths examined under IBC1 total 4,990 metric tons of rare earth oxides, valued at $496 million.

Lithium, the alkali metal with the lowest atomic number, is used in a variety of applications, including, ceramics and glass, batteries, lubricating greases, aluminum production processing, air treatment, continuous casting, chemical processing, and pharmaceuticals. The fastest-growing application for lithium is expected to be batteries, especially rechargeable batteries. Some lithium batteries have significant defense applications.

The U.S. Geological Survey provided supply and demand information for lithium, similar to the information it provides for the standard and specialty materials. From this

information, data for shortfall computation were assembled. The initial results, however, showed no shortfall in IBC1, with a ratio of potentially available supply to demand of over three to one.

B. Specialty Steels

IDA has compiled supply and demand data for three types of specialty steels: type M50, type 300M, and steels used in armor for combat vehicles ("armor steels"). The DNSC request for IDA to compile this information was based chiefly on the long lead times experienced by DOD or DOD vendors in the past several years in obtaining those steels for use in military equipment.

1. Type M50

Type M50 is a low-alloy, vacuum-melted, intermediate high speed, molybdenum type tool steel. The steel is produced by processing in vacuum induction melt (VIM) and then vacuum arc re-melt (VAR) furnaces. Both types of furnace are necessary to produce the steel and thus its production capacity is limited by the availability of both types of furnace rather than one or the other. M50 is used in jet and helicopter engine bearings and shafts, mostly (75 percent) in military applications.[20]

Three U.S. firms can produce M50 steel: Latrobe Specialty Steel, Carpenter Technology Corp., and Allegheny Technologies, Inc. (ATI). These firms do not all produce the material at any given time.[21] Total U.S. VIM capacity is approximately 27,000 tons per year.[22] Total U.S. VAR capacity is approximately 45,000 tons per year.[23] Prior to a 2005-07 surge in demand for M50, U.S. production (and consumption) was approximately 2,500 tons per year. Thus, approximately 7 percent of U.S. VAR output consisted of M50 or similar type steels, 35 percent consisted of 300M or similar type steels, and the remaining 58 percent consisted of nickel alloys, stainless steels, and titanium.[24] For the IBC1 assessment, we assumed that VAR capacity would be similarly utilized to meet scenario demands for M50 and 300M and presumed scenario demands

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20 "Iron Based, Low Alloy VIM-VAR Steel Assessment," Office of Secretary of Defense Supply Chain Working Group, April 2007, p. 26 [hereinafter "Supply Chain Working Group"].

21 Telephone conversation with Robert Olson, Aviation Industrial Base Team Lead, U.S. Army Aviation and Missile Research Development and Engineering Center, Engineering Directorate, Industrial Operations Division, January 2010.

22 Telephone conversation with Mark Werberding, Vice President, Marketing and Sales, Latrobe Specialty Steels, February 2010. Latrobe recently expanded its VIM capacity with assistance from a DOD Defense Production Act Title III investment intended to mitigate long lead times for M50 steel caused by demands arising out of the Iraq and Afghanistan wars and a boom in the international aerospace sector. Telephone conversation with Robert Olson.

23 Telephone conversation with Mark Werberding.

24 Ibid.

for nickel alloys, stainless steels, and titanium.[25] Thus, only 7 percent of U.S. VAR capacity, or 3,150 tons per year, would be available to produce M50 steel.[26] Therefore, under our assumptions, VAR capacity limits total U.S. M50 production.

Three foreign countries can also produce M50 or similar type steels: France, Austria, and Taiwan. We were only able to obtain data on French production capacity. Assuming for stockpile scenario planning purposes that available capacity is split between M50 type steel and 300M type steel in the same proportions as it is for peacetime production, 4,250 tons per year would be potentially available to the U.S. to produce M50 for the scenario.[27]

The wartime scenario (Interim Base Case1) demand for M50 steel was projected using IDA's Proxy MCR methodology for estimating demand for specialty materials (see Appendix C of this report). The initial comparison of demand to supply (Table 3-4) shows that no shortfall would be experienced during any year of the scenario.

2. Type 300M

Type 300M is a low-alloy, vacuum-melted, high-strength steel. It is produced in VAR (not VIM) furnaces. Almost all 300M (98 percent) is used in aircraft components (landing gear, wing flap tracks, actuators and valves, structure). About 15 percent of those components are for military aircraft; 85 percent are for civilian aircraft. The remainder (2 percent) is used in military armored vehicles.[28]

Seven U.S. firms can produce 300M steel. Total U.S. VAR capacity is approximately 45,000 tons per year. In recent years, U.S. production (and consumption) was about 12,500 tons. In a typical peacetime year, 35 percent of U.S. VAR output consists of 300M or similar type steels.[29] Thus, similarly to the approach we took with

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[25] Because we do not model all of those materials (nickel alloys, stainless steels, and titanium), we cannot project exactly how much VAR capacity would be needed to meet demands for them. We conservatively assume that 58 percent would continue to be needed during the scenario to meet demands for them to avoid relying on VAR capacity for M50 that would potentially be unavailable.

[26] We assume that unused VAR capacity would be available to produce alloys in the same proportion as the capacity used in a typical year. Thus only 7 percent of unused capacity is available to produce M50; the remaining unused capacity is set aside for potential use to produce 300M and similar steels and the other (Ni, stainless, Ti) alloys, all of which might also experience increases in demand during a wartime scenario.

[27] Source for French capacity: telephone conversation with Mark Werberding. Thus, while France may appear to be a dominant producer of M50, it likely produces less than 50 percent of the world's supply given Austrian and Taiwanese production as well. Note that U.S. usage of available foreign production capacity during the stockpile planning scenario depends on U.S. ability to "bid" for that capacity as projected by the IDA stockpile requirements methodology.

[28] Telephone conversation with Mark Werberding.

[29] Ibid.

M50 described above, we assumed that only 35 percent of U.S. VAR capacity, or 15,650 tons per year, would be available to produce 300M steel.[30]

Four other countries can produce 300M or similar type steels: the United Kingdom, France, Austria, and Taiwan. We were able to obtain data on U.K. and French production capacities. Assuming that available French capacity is split between M50 type steel and 300M type steel in the same proportions as it is for peacetime production, 21,250 tons per year would be potentially available to the U.S. to produce 300M for the scenario.[31] U.K. capacity is 12,750 tons per year, from VAR furnaces only, so we assume that all of it is potentially available to the U.S. to produce 300M steel.[32]

Interim Base Case demand for 300M steel was projected using IDA's methodology for estimating demand for specialty materials. A comparison of demand to supply showed that no shortfall would likely be experienced by the United States during any year of the scenario.

3. Armor Steels

In the United States, two types of steel are used for almost all of the steel armor in armored vehicles: rolled homogeneous armor (RHA) and high hardness wrought steel plate ("high hard armor" or HHA).[33] Almost all of those two steels used in the United States are applied to armored vehicles for DOD. U.S. peacetime demand for these steels is estimated to be approximately 53,400 tons of RHA and HHA, collectively, per year.[34]

In the United States, three firms, Arcellor-Mittal, Evraz Oregon Steel Mills, and Clifton Steel, produce (heat treat) both RHA and HHA.[35] The facilities used to produce both types of steel are the same. The ability to produce the steels for DOD depends on

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[30] As noted above, we assume that unused VAR capacity would be available to produce different alloys in the same proportion as the capacity is used in a typical year.

[31] Source for French capacity: telephone conversation with Mark Werberding. U.S. usage of available foreign production capacity depends on U.S. ability to "bid" for that capacity during the scenario.

[32] Source for U.K. capacity: telephone conversation with Mark Werberding.

[33] E-mail communication, U.S. Army Research, Development, and Engineering Command-Tank Automotive Research, Development and Engineering Center, Industrial Base Engineering Team, February 2010.

[34] Defense Contract Management Agency, *DOD Armor and Steel Requirements —Chart 26*, October 2007; telephone conversations with Roudy Romulus, Defense Contract Management Agency, February 2010. The estimate includes surge demand in 2007 as well as more typical demands in 2008 and 2009, so it represents a somewhat conservative peacetime demand estimate.

[35] Arcellor-Mittal has its own steel slab melting capacity; Oregon Steel procures steel slabs from Mexico; and Clifton procures slabs from firms in the U.S. and Canada.

being appropriately qualified. Total U.S. production capacity for RHA and HHA is 188,400 tons per year.[36]

Four foreign countries, Australia, Canada, Germany, and Sweden, can produce both RHA and HHA. Total foreign production capacity potentially available to the United States is 93,960 tons per year.[37]

The wartime scenario (Interim Base Case 1) demand for armor steels was projected using IDA's methodology for estimating demand for specialty materials. A comparison of demand to the supply figures assessed above showed that no shortfall would be experienced during any year of the scenario.

C. High Performance Fibers

IDA collected and assessed supply and demand data for three categories of manmade, high performance fibers: carbon, silica, and aramids. Five specific fiber types were assessed: polyacrylonitrile (PAN)[38] based carbon fibers, high-purity quartz fiber,[39] and high-strength structural glass fiber, and para- and meta- aramid fibers. A total of nine individual fibers were selected by DOD for evaluation:

- Five carbon fibers (AS-4, IM-6, IM-7, T-300, and T-700)
- Two silica fibers (Quartzel high-purity quartz fiber and S-2 Glass fiber)
- Two aramid fibers (Kevlar para-aramid and Nomex meta-aramid fibers)

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36 *DOD Armor and Steel Requirements—Chart 26*, October 2007; telephone conversations with Roudy Romulus, Defense Contract Management Agency, February 2010.

37 As with other candidate materials, actual U.S. usage of foreign capacity depends on U.S. ability to "bid" for that capacity during the scenario.

38 While there exist a few dozen variations of carbon fibers made from PAN, PAN fibers are commonly distinguished as either "small tow" or "large tow," which refers to the diameter of a fiber. The diameter is determined by the number of individual fiber filaments used to produce a fiber. Small tow carbon fiber (made from 1,000 to 24,000 filaments) is twice as common as large tow fiber (48,000 to 320,000 filaments). Small tow fibers include a wide a range of performance properties such as modulus (i.e. stiffness) including low (<32 Msi), standard (33 to 36 Msi), intermediate (40 to 50 Msi), high (50 to 70 Msi) and ultra high (70 to 140 Msi) modulus. Small tow carbon fibers are commonly referred to as "aerospace" grade and large tow fibers are commonly referred to as commercial grade (Msi data from *High Performance Composites* magazine). The focus of this report is on small tow fiber.

39 While DOD selected the generic term of "high-purity quartz fiber," there is essentially one global producer of this product, the Saint Gobain company of France. Saint Gobain has industrial scale capabilities in France and the U.S. Its quartz fiber is widely qualified within U.S. and European defense, space and commercial aircraft applications. However, there was a joint U.S. Army and Air Force Title III program to develop a domestic quartz fiber and production capability. The contract was award to Fiber Materials, Inc. (FMI) of Biddeford, Maine in 1988. Although FMI developed quartz fiber and a production facility in OH, difficulties were encountered in getting FMI's material qualified for use on U.S. defense programs. FMI's Title III program ended in 1992. It is not believed that its products were ever qualified for any DOD defense programs. Although FMI's quartz fiber plant is reported to be "in-place," it is also believed to be in an idle state.

The industrial base for high performance fibers is relatively small in comparison to greater numbers of larger manufacturers of commercial grades of textile fibers and other relevant commodities such as chemical producers. Worldwide, there are presently six commercial scale producers of carbon fibers; two leading producers of aramids; one DOD qualified producer of structural fiberglass and one commercial scale producer of high-purity quartz fiber. Fiber manufacturers for the nine fibers above are produced by six companies, including four U.S. firms, one Japanese-based firm, and one French-based firm, both of whom manufacture fibers domestically in U.S. subsidiary factories.

The origins of these manmade fibers trace back to the development and initial commercialization of high performance fibers from the late 1950s to the early 1980s. High performance fibers were being developed as a reinforcement for new advanced composite materials also under development. This was an outgrowth of the development and first widespread use of simpler composites produced for aircraft and ships during World War II. These earlier polymer based composites utilized lower performance commercial grades of fiberglass to reinforce plastics. Throughout the Cold War, the U.S. military took interest in the subsequent development of high performance fibers that would enable a new generation of "advanced" composites[40] for applications such as intercontinental ballistic missiles (ICBMs), stealth aircraft and satellites.[41] Other uses have evolved during current conflicts in Iraq and Afghanistan including unmanned air vehicles, body armor, and ballistic protection of ground vehicles.

While military requirements earlier dominated demand for high performance fibers and advanced composites,[42] commercial applications and demand eventually grew much faster and today far exceeds military demand by a factor on the order of ten to one in many markets. Civilian applications include materials and structures for commercial aircraft, boat building, automotive, industrial equipment, construction materials, recreational products as well as energy (e.g., nuclear, oil, electricity and wind). Nevertheless, demand for certain fibers can still be largely dominated by defense needs.

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[40] While polymer matrix composites have traditionally been made from thermoset resins, such as epoxy, thermoplastic resins are becoming increasingly popular.

[41] A small number of the nine fibers assessed, in particular Kevlar and Nomex, have traditionally been used mostly in the finished form of textile products versus being incorporated into composite materials. Military applications for textiles include "soft" body armor; spall liners for combat vehicles; flame protection garments; and protective braided sleeves for hoses and cable. However, composite applications for these fibers (e.g., aircraft structures and vehicle armor) are growing.

[42] According to a 2005 report by the National Materials Advisory Board, *High-Performance Structural Fibers for Advanced Polymer Matrix Composites*, DOD use of carbon fibers represented about two thirds of domestic demand in 1981. By 1999, DOD demand represented less than 10 percent of domestic use. More current estimates indicate this projected ten to one ratio of commercial to military demand is still relevant. Although it is the exception, there are some high performance fibers where DOD makes up the majority of demand.

High performance fibers enable the manufacture of very light weight structures with exceptionally high specific strength, stiffness, and impact resistance well beyond conventional materials. In addition to highly tailorable and superior mechanical properties, high performance fibers impart other desirable characteristics in composites such as high temperature resistance, electromagnetic transparency, dimensional stability, anticorrosion and anisotropic properties including thermal and electrical conductivity, and insulation.

With one exception,[43] all nine fibers are unique products that are particular to one company. As such, supply and demand data are proprietary and not publicly available. Supply and demand data required for this report are not maintained by any known U.S. government sources including USGS, DOC, and DOD. Required data were also unavailable from third party commercial sources including trade associations, business publications, and industry consultants. While limited supply and demand information is published by third party sources for some of the three categories of fibers mentioned above (primarily carbon), these data are aggregated and not suitable for modeling stockpile requirements (e.g., combining data of multiple fibers from multiple producers whose products may be similar but not identical to specific fibers of interest for this report). In addition, data reported by third party sources often may not be in agreement with manufacturers, and in fact, conflict with producer estimates. Given these constraints, IDA relied on fiber manufacturers to voluntarily provide data required for this report. The accuracy and reliability of this data can be especially high compared to third party government and industry sources. All but one[44] of the six producers of the nine fibers provided IDA with requested data. Alternative sources were developed for data on the fiber from the remaining producer and they were sufficient for IDA to perform its analysis.

Although supply and demand data are not publicly available for individual fibers, aggregated data can still provide useful insights and greater context into the broader markets for high performance fiber. Examples of aggregated carbon fiber supply and demand (worldwide) data include:

- Annual production capacity[45] of carbon fiber in 2010 is estimated at 62,000 MT and is projected to slightly increase to 67,000 MT by 2014.[46]

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43 An exception is T-300 which is manufactured by two firms. Although not identical, T-300 fibers from each supplier are very similar and treated as one for the purpose of this report.

44 IDA was unable to collect supply and demand data on T-300 carbon fibers produced by Cytec.

45 Industry stated production capacities of carbon fiber plants can be fluctuate sharply (+/- 30 percent to 40 percent) due to high product variability which can significantly reduce production output. For example, producing a higher performance grade of carbon fiber takes much more processing time which can greatly reduce stated capacity to produce lower performance fibers. Carbon fiber manufacturers state their production capacity based on producing standard performance materials.

- Annual demand[47] for carbon fiber in 2010 is estimated at 39,000 MT and is expected to increase nearly threefold to 112,000 MT by 2018.[48]
- The market for carbon fiber is expected to grow 60 percent, from $1.5 billion in 2008 to $2.4 billion in 2014.[49]
- Current consumption of small tow carbon fiber includes Japan (38 percent), North America (22 percent), Europe (19 percent) and the rest of Asia (10 percent).[50]

Although quite limited in comparison to publicly reported data on carbon fiber, aggregated data has been openly reported on other categories of high performance fibers assessed in this report such as aramids, glass, and quartz fiber. Examples of the annual demand in 2006 for fibers used as a reenforcement material in manufacturing composites includes:[51]

- High strength fiberglass:[52] 2,300 MT and $41 million
- Aramid fibers (of all types): 28,000 MT and $1.06 billion
- Commercial grade fiberglass (e.g., E-Glass): 1,300,000 MT and $2.44 billion
- Carbon fibers (small and large tow): 27,000 MT and $1.3 billion

The demand for high performance fibers has steady grown over the past thirty to fifty years. However, there have been boom and bust periods of strong growth and sharp declines in demand accompanied by price volatility, supply chain disruptions, plant closures, and industry consolidations. Up until the recent recession, the market for high performance fibers has generally experienced tight supplies throughout much of the last decade, accompanied by third party estimates of multiyear shortfalls of 10 to 15 percent (i.e., percent of unmet demand). While supply and demand can vary by individual fibers and the cyclical nature of different sectors, rapid growth in numerous commercial markets globally coincided with a surge in unanticipated wartime demand during this period. In response to growing demand, nearly all leading fiber producers made significant investments in major plant expansions over the latter part of the past decade. However, the severity of the recent recession, coupled with a sharp drop in U.S. demand

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46 "Carbon Fiber: Supply and Demand Forecast," High Performance Composites, *Composites World*, December 16, 2009. Note that capacity figures include a downward adjustment to industry stated "name plate" capacity of approximately 35 percent to account for product variability.

47 Ibid.

48 Small tow aerospace grade carbon fiber.

49 "Report: Carbon Fiber Market Will Reach $2.4 Billion by 2014," according to a market study from the consulting firm Lucientle and as reported by *Composites World*, May 26, 2009.

50 "Carbon Fibers 2009" conference proceedings published by *Composites World*.

51 Tony Roberts, "The Carbon Fiber Industry: Global Strategic Market Evaluation 2006-2010," *Materials Technology Publications*, 2006.

52 R/S/T glass fibers

for certain war materiel, has significantly impacted fiber producers (e.g., delayed expansions, idling of existing capacities, and worker layoffs).

Ease of possible substitution among high performance fibers varies. While different fibers exist and compete within the same fiber categories and fiber types identified above, fibers are often not readily interchangeable for many applications especially after the development of end-use designs, requirements, and qualifications. Unless multiple fibers were qualified together, it can be very difficult, and at times practically impossible, to substitute one fiber for another without extensive requalification. For defense and commercial aerospace applications, this can be a lengthy and costly process requiring a year or more of effort and millions of dollars.

The underlying material science, manufacturing processes, and production equipment used to produce fibers within the three categories identified for this study are very different and involve many complexities. Would-be competitors face steep barriers to market entry. For example, many industrial commodities are homogenous with standardized materials produced around open standards such as those used to manufacture various metals. High performance fibers and advanced composites are often individually tailored materials with heterogeneous properties that are unique to individual companies and proprietary “black box” processes. Few countries have mastered these capabilities over the last three to five decades. In addition to the high cost of qualifying fibers, it can take one to two years and a $100 to $500 million[53] to design and construct a fiber production line.

While only one of the nine fibers evaluated under the IBC1 scenario experienced a shortfall, six experienced near shortfalls (e.g., supply to demand ratios less than 2.0). The projected supply of only one fiber was considered clearly sufficient under the IBC1 scenario. While researching fiber manufacturers for this report, it was noted that during extended periods over the last decade, U.S. producers of high performance fibers regularly received Defense Priorities and Allocations System (DPAS) rated orders. It was also noted that DOD invested in qualifying both direct substitutes and alternative materials to replace or complement incumbent fibers such as those needed to satisfy unanticipated and urgent warfighter needs from Iraq and Afghanistan (e.g., body armor and ballistic protection for combat vehicles). In addition, DOD established buffer stocks for certain fibers while foreign fiber producers were granted waivers to import restrictions under the Berry Amendment.[54]

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[53] Reported cost of DuPont’s new Kevlar factory in South Carolina.

[54] General provisions of the *Berry Amendment*, U.S. Code 10 (2010), § 2533a, requires DOD to purchase textiles with high performance fibers manufactured from domestic sources. While the law applies to textiles used in apparel for applications such as soft body armor and flame protection garments, it apparently does not apply to textiles intended for use in manufacturing composite materials.

Provided next is a summary of nonproprietary information for the nine fibers evaluated for this report, including IBC1 scenario modeling results for supply and demand ratios.

1. Carbon Fibers

Carbon fibers were developed in the late 1950s and early 1960s in Japan, England, and the U.S. Although different types of carbon fibers exist, including those made from other precursor materials such a rayon and petroleum pitch, PAN-based carbon fibers[55] are the most versatile and common type of carbon fiber used for the greatest number of commercial and military applications. Compared to other high performance fibers used for advanced composites applications, carbon fiber is much more widely used for defense than any other fibers.

The three leading producers are Japanese-based firms (Toray, Toho and Mitsubishi) who account for an estimated 70 percent[56] of worldwide production capacity with factories in Japan, France, and the U.S. Two leading U.S.-based producers (Hexcel and Cytec) together represent just over 16 percent[57] of the world's capacity.[58] Both firms have plants in the United States (South Carolina and Utah) while Hexcel also has a plant in Spain. Hexcel is the largest producer of the two and by far the world's largest supplier of carbon fiber to DOD, with an estimated market share of 90 percent or greater.

Manufacturers of the five PAN-based carbon fibers assessed for this report and their respective products include: Cytec (T-300); Hexcel (AS-4, IM-6 and IM-7); and Toray (T-300 and T-700). Military applications for these fibers include manned and unmanned aircraft, tactical and strategic missiles, space launch vehicles and satellites, as well as emergent uses in ground combat vehicles and U.S. Navy ships.

IM-6 was the only carbon fiber to show a shortfall with a supply to demand ratio of 0.96 while near shortfalls were shown for AS-4 (1.78), IM-7 (1.43) and T-300 (1.73). No shortfalls were demonstrated for T-700 (5.32).

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55 The precursor material to PAN-based carbon fibers is made from modified polyacrylonitrile which is derived from the common chemicals propylene and ammonia.

56 "Carbon Fibers 2009" conference proceedings published by *Composites World*, December 2009.

57 "Carbon Fibers 2009" conference proceedings published by *Composites World*, December 2009.

58 Formosa Plastics of Taiwan produces carbon fiber including aerospace grade material and is reported to have volume capacities on the order of 7,000 MT. In addition to some of the firms cited in this report, other companies produce non-aerospace grades of carbon fiber in the U.S., Germany and Hungary. There are numerous carbon fiber start up and early stage ventures reported in China, Russia, India, Saudi Arabia, and Turkey. Although the U.K. was an original developer of carbon fibers, its global position has diminished and is largely concentrated on producing precursor materials for industrial textile grades of carbon fiber.

2. Silica Fibers

The S-2 Glass brand of structural fiberglass and the Quartzel brand of high-purity quartz fiber are derived from silica.

The U.S.-based company, AGY, Inc. (formerly Owens Corning), is the sole producer of S-2 Glass[59] fiber with production lines in South Carolina and Pennsylvania. S-2 contains mostly silica (64 to 66 percent)[60] along with alumina, magnesia, and other materials. S-2 was initially developed in the early 1950s and its first major application was for U.S. ballistic missiles in the early 1960s. AGY's predecessor company, Owens Corning, created fiberglass in the 1930s. While AGY produces much larger volumes of commodity grades of fiberglass (representing 90 percent of all fiberglass produced) S-2 Glass is a higher performance and more costly material. Military applications include body armor, vehicle protection, and structures for aircraft and ships.

Estimates of the scenario supply and demand for S-2 Glass demonstrated a near shortfall with a supply to demand ratio of 1.28.

Another silica based fiber of great importance to DOD is high-purity quartz fiber (99.99 percent silica). The French company, Saint Gobain, is the only known commercial scale manufacturer of this material. Produced under the trade name Quartzel, it is manufactured both in France and at a U.S. subsidiary factory (Kentucky). Quartzel was first developed in France in 1963 for military applications and ballistic missiles in particular. Saint Gobain established a U.S. plant in Kentucky in 1985 to support a variety of DOD weapon systems including stealth bomber and fighter aircraft, missiles and launch vehicles, naval surface ships, and submarines. Unlike other silica based fibers, quartz offers a unique combination of much higher strength and temperature resistance as well as greater electromagnetic transparency. Although historically used for mostly defense, Quartzel is increasingly used in commercial applications such as civilian aircraft radomes and antenna windows.

Estimates of the scenario supply and demand ratio for Quartzel fiber were calculated and are availalbe to the sponosr upon request.

3. Aramid Fibers

Kevlar and Nomex are aramid fibers derived from aromatic polyamide. The U.S.-based company, DuPont, is the sole producer of both products with U.S. plants in

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59 There are other startup producers of structural fiberglass in the U.S. including Owens Corning Vetrotex (OCV) and PPG Industries. Established producers of similar materials also exist in Asia and Europe.

60 Ginger Gardiner, "The Making of Glass Fiber," High Performance Composites, *Composites Technology*, March 25, 2009.

Virginia and a new Kevlar plant under development in South Carolina. DuPont also produces Kevlar in Ireland and Nomex in Spain.

Nomex is a meta-aramid fiber first developed by DuPont in the early 1960s. It has traditionally been used in soft textile form in flame protection apparel for military personnel, civilian first responders, and industrial workers. Other dual use applications include textiles for insulation for equipment and as a reinforcement for aircraft composites.

Estimates of the scenario supply and demand for Nomex demonstrated a near shortfall with a supply to demand ratio of 1.15.

Kevlar is a para-aramid fiber first developed by DuPont in the mid 1960s. It has traditionally been used in soft textile form for body armor for the military and civilian law enforcement as well as protective apparel for industrial workers. Other dual use applications include soft textile forms for thermal and electrical insulation of equipment and reinforcement for automobile tires and engine belts. Kevlar is also used as a reinforcement for composites in soldier helmets, body armor, and blast protection for ground combat vehicles as well as structures for commercial and military aircraft and rocket motors.

Estimates of the scenario supply and demand for Kevlar demonstrated a near shortfall with a supply to demand ratio of 1.16.

4. Other Fibers

Although collecting data and modeling potential shortfalls of other fibers was beyond the scope of this report, industry and government contacts identified three other types of high performance fibers that are especially important to a number of critical weapon systems and whose future supply faces inherently high risk. The first fiber type is high and ultra high modulus carbon fibers that are produced in limited quantities by a single supplier in Japan. These materials are important to satellites, missiles and unmanned ISR aircraft. The second fiber type is rayon based carbon fiber which is the only type of carbon fiber suitable for solid rocket motor exit cones for various missiles including ICBMs and missile defense systems. This material is also produced in limited quantities and by a single foreign supplier located in Germany. Rayon based carbon fiber was earlier stockpiled by the U.S. Navy, Missile Defense Agency (MDA), and National Aeronautics and Space Administration (NASA). However this supply is reported to be on the verge of running out. The third fiber type is silicon carbide fiber[61] which is produced

[61] Multi filament small tow versus mono filament fiber produced domestically from a single source and in small quantities.

in limited quantities by only two foreign suppliers, both located in Japan. This material supports special capabilities for key defense systems.

5. Interim Base Case Results

Of the high performance fibers assessed in the IBC1 scenario, only one, IM-6, evidenced a shortfall. This shortfall would probably not occur, however, if the existing unused capacity could be more fully utilized during the first year of the scenario.

D. Discussion

It has proven feasible to obtain a preliminary data set on most of the “new” materials IDA has sought. This has been possible only through the timely and outstanding cooperation of the USGS and a number of U.S. firms. Much of the underlying data are deemed “company proprietary,” and thus are quite limited in their distribution. These data, while already available to the sponsor, may be provided in a subsequent IDA document if the sponsor determines that is appropriate.

This chapter has presented preliminary findings for seventeen of the “new” materials, founded upon the Interim Base Case described in Chapter One. The results suggest that the DOD is well-advised to consider carefully the possibility of shortfalls of materials such as these—perhaps most notably the rare earths—in planning cases such as IBC1 and the forthcoming 2011 NDS/SMSP Base Case. The data that IDA has collected on these new materials are now ready to be integrated into the regular assessments for the *2011 NDS/SMSP Requirements Report to Congress*.

4. Purchasing Efficiencies for DOD Materials—Roles and Options for the Defense National Stockpile Center (DNSC)

Defense production requires large quantities of materials. For the most part those materials are purchased in a decentralized manner by the prime contractors, subcontractors, and program offices associated with individual programs. At the same time, DNSC has expertise in materials markets, gained over the years by buying and selling strategic and critical materials (SCMs) for the National Defense Stockpile (NDS). Would the government benefit if DNSC played a larger role in procuring defense materials? For example, if DNSC negotiated contracts on behalf of multiple programs, could it achieve lower prices or better terms than the current approach? The following discussion explores this possibility at a summary level.

The basic proposition is that by applying its expertise and negotiating contracts for larger quantities of materials, DNSC might achieve better results than individual contractors and programs do today. There are many models that could be adopted. For example, several programs that need a particular material might offer their requirements up to DNSC, which would negotiate a combined procurement contract for the material. The individual programs would buy their requirements under the DNSC-negotiated contract. Under a riskier alternative, DNSC might negotiate contracts in anticipation of program needs, taking responsibility for any contracted materials that programs did not buy. The contracts could be designed to meet immediate needs or to establish long-term relationships with material suppliers.

The following sections consider the potential benefits of a larger DNSC role. They also identify implementation issues that must be addressed.

A. Price Discounts through Larger, Centralized Contracts

Price discounts for bulk purchases are a common feature for many products at the wholesale level. If DNSC negotiates for larger material buys covering multiple

programs, it may be able to elicit lower prices than the programs negotiate individually.[62] Vendors may offer such discounts for several reasons, including:

- Price discrimination
- Vendor cost savings
- Long-term relationships

1. Price Discrimination

In highly competitive materials markets, producers can generally sell all of their output at the market price. There is little reason for them to cut price below the market price in order to increase sales. However, in markets where competition is imperfect, dominant producers with market power may limit their output in order to support higher prices. In some cases, dominant producers engage in price discrimination, charging a high price to the general market but offering a lower price selectively to gain the business of certain large, price-sensitive customers.

The dynamics of price-setting and competition in materials markets are not always obvious to outsiders. Opportunities for price discrimination nevertheless seem more likely for materials whose producers set their own list prices or negotiate benchmark prices with major producers. Examples include titanium metal, beryllium, and iron ore (although the latter is not an SCM). Chances for price discrimination seem less likely for globally competitive materials listed on major exchanges. The London Metals Exchange (LME), for example, offers futures contracts for aluminum, copper, tin, nickel, zinc, and lead. However, while LME prices are often used as reference prices for sales transacted elsewhere, that does not necessarily preclude price discrimination.

2. Vendor Cost Savings

If the unit cost to the vendor is lower for bulk orders, the vendor may pass on part of the savings to the customer. This should particularly be expected in highly competitive markets. Such cost savings may result from economies of scale in manufacturing, for example, if the customer is ordering a specialized model or a particularly high-purity material. Savings may also result if multiple negotiations and contract finalizations consistent with DOD-specific regulations are combined into a single event. There may also be savings in product distribution, including shipping and warehousing.

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[62] Price determination for materials is highly dynamic and not always transparent to an outside observer. Price structures vary from material to material and depend importantly on the supply-demand balance at a given time. Ultimately, the prices at which DNSC could buy materials must be determined through competitive bidding or negotiation. The following discussion does not attempt to quantify those prices or the discounts they may embody.

The vendor may also realize cost savings by transferring certain responsibilities to the customer. Lower costs associated with such transfers may or may not represent a net benefit to DOD. For example, the vendor might offer to deliver materials to DNSC and expect DNSC to arrange for delivery to defense programs and producers. Whether the discount would cover the added costs imposed on DNSC would have to be determined case by case.

For purposes of reducing unit costs (to the vendor and DOD), the combined orders need not represent a large share of the vendor's sales. More important is how large a combined order is compared to the individual orders that are combined. Consolidating a number of tiny nuisance orders into one modest order may generate a beneficial reduction in the unit cost.

B. Other Contractual Benefits: Assured Supplies

Another key DOD objective is to assure access to materials during periods of supply shortage. One way to achieve this is to build long-term contractual relationships with material suppliers. Multi-year contracts can specify, for each period, maximum quantities of materials that vendors agree to supply if needed as well as minimum quantities that customers agree to buy. This helps stabilize vendor sales since the customer continues buying even during periods of low demand. It similarly helps stabilize customer supplies since the vendor keeps selling even during periods of material shortage. Stability of supply may also include provisions for minimum and maximum order lead times. Various contingency contracts could also be negotiated to ensure material supplies without necessarily committing DOD to buy.

Long-term contracts must specify a mechanism for price determination. For example, it may be desirable to stabilize prices so that they do not drop too low (for the vendor) during periods of low demand or spike too high (for the customer) during periods of short supply. Price stability may enable better planning by both the vendor and the customer. Alternatively, the contract might link prices to a reference market price or an inflation index. In general, which approach is most advantageous for DOD would depend on the circumstances. Some vendors may offer price concessions in order to cement a steady flow of orders. Or DOD may be willing to pay a bit more to ensure against running short of funds when prices unexpectedly spike.

Both the scale and the stability of material requirements are important for successfully negotiating long-term supply arrangements. The needs of individual programs are often not only small but also quite volatile. Frequent changes in defense programs can lead to stop-and-go, up-and-down changes in material requirements that make long-term commitments infeasible. However, these perturbations may offset one another to some degree when the requirements of multiple programs are aggregated.

That is, combined requirements may be more stable as well as larger.[63] The ability of DNSC to negotiate based on combined requirements may thus be an enabler for long-term commitments that would otherwise be imprudent for DOD or uninteresting for vendors.

While long-term contracts can contribute to assuring supply during periods of shortage, it is important to keep in mind the capabilities of the Defense Priorities and Allocations System (DPAS). The DPAS authorities can be invoked to ensure that material requirements for rated defense contracts and subcontracts are met, even during periods of material shortage. Supply assurances under long-term contracts could thus be considered redundant. As a practical matter, however, the effectiveness of DPAS is sometimes limited in order to avoid undue civilian hardship or market disruption. In any case, DPAS cannot substitute for the price stabilization benefits that may be included in long-term contracts.

C. DOD Administrative and Operational Efficiencies

The discussion above focuses on contractual benefits DNSC could negotiate with vendors. In addition, there are potential efficiencies DOD could achieve in the way it manages the supply of materials. These include:

- Cost discipline in the procurement of materials
- Return of scrap value to the government
- Shock absorber for unexpected program changes

1. Cost Discipline in the Procurement of Materials

DOD may be more concerned than defense contractors and subcontractors about controlling material procurement costs. Particularly when cost-reimbursement contracts are used, the incentives for defense producers to control costs can be relatively weak. It may be possible, in some cases, to reduce material costs by having DNSC rather than the defense contractor or subcontractor negotiate material procurement. This could be true even if vendors do not offer price concessions for bulk purchases.

DNSC potentially has expertise at buying specific materials that is not available at many of the program offices that oversee defense programs. The program offices can leverage that expertise by asking DNSC to negotiate material procurement contracts. The program offices can then buy the materials and provide them as government-furnished material (GFM) to the defense contractor or subcontractor. This approach may also avoid any markup the defense contractor charges the government for the materials it buys.

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[63] The stability of requirements should tend to increase as the number of programs combined increases.

Alternatively, the program offices can direct defense contractors to buy required materials under the DNSC-negotiated agreement. In either case, prices for the materials would be negotiated by a (presumably) cost-conscious government expert rather than a (possibly) indifferent contractor.

2. Return of Scrap Value to the Government

Another potential benefit from providing materials to the contractor as GFM is that the government can set conditions for the use of that material, including a requirement that leftover material and process scrap be returned to the government. The cutting, squeezing, and shaving necessary to manufacture a complex part can generate a substantial amount of metal scrap, sometimes amounting to more than 95 percent of the starting quantity of material. This scrap may have significant market value if it is segregated by type of material and kept uncontaminated. Similarly, some of the purchased material will go unused if safety margins are built into the buy requirement. Typically, the contractor or subcontractor seems to retain the value of scrap or excess material that it buys. The case for government ownership of the residual material seems stronger when the material is provided as GFM.

Scrap recovery can thus be a side benefit of providing material as GFM, provided that the program office takes the initiative to recover the scrap. In cases where the program office does not have the expertise to negotiate the procurement of particular materials, DNSC can thus play an enabling role for both GFM and return of scrap value.

3. Shock Absorber for Unexpected Program Changes

The discussion above notes that aggregated defense demands for materials may be more stable than the demands of individual defense programs since some of the perturbations that afflict individual programs will offset one another. To the extent that this is true, it is an enabler for negotiating multi-program buy commitments that would be imprudent to negotiate for individual programs. This section considers other ways DOD could take advantage of this phenomenon.

If DNSC obtains inventories of materials, real or virtual, it can offer them to individual programs on an as needed basis. Programs whose requirements unexpectedly decrease can reduce their buys, avoiding the cost of excess inventories and contractual take-or-pay obligations. And programs whose requirements unexpectedly increase can quickly boost their buys without renegotiating contracts or enduring long lead times. To the extent that aggregate material demands for the participating programs remain stable, this flexibility can be utilized without increasing, and possibly decreasing, the aggregate cost of the materials to DOD.

DNSC access to the required materials could be provided through a mix of long-term procurement contracts, contingency contracts, and vendor-held buffer stocks. DNSC might also hold physical inventories to serve as planned buffer stocks or to absorb take-or-pay obligations under the procurement contracts.

Admittedly, it would be a challenge to achieve this feat. The aggregate demands of the likely participants would have to be forecast well and provisions would be needed to limit adverse "gaming" of the initiative by the programs. Some residual costs would be incurred by DNSC, for example, buying and/or holding excess inventories and coordinating requirements. If the aggregated demands of the participating programs are too volatile, the initiative might prove to be infeasible.

D. Implementation Considerations

To enable DNSC negotiations and take advantage of the resulting material procurement contracts, a number of implementation issues must be addressed. This section discusses some examples, namely:

- Reluctance of programs to participate
- Defense contract issues
- Additional costs to the government
- Vendor interest in negotiations
- Foreign sources

1. Reluctance of Programs to Participate

Some contractors and/or program offices will choose not to participate. For them, the potential advantages of DNSC-negotiated contracts will not be sufficient to justify abandoning their existing approaches. Potential reasons for non-participation include:

- Existing relationships with material suppliers
- Capability to negotiate their own deals
- Preference for flexibility across material cycle

Defense contractors and subcontractors have ongoing relationships with material suppliers other than the DNSC vendors. They may trust their suppliers to meet their needs. Their suppliers may offer particular advantages such as convenient locations or specialized capabilities. Programs may have "qualified" particular suppliers to meet stringent material specifications. In some cases, companies that manufacture components will have their own in-house material sources. Further, some contractors may see advantages in using the same material source for both their commercial and their defense

business. The benefits of an effective relationship with an existing material supplier may well be worth more than the advantages of a DNSC-negotiated contract.

Further, large defense contractors may be experts at buying the materials they need. Their orders may be large enough that they can demand and receive a material vendor's best price and terms. Boeing Commercial certainly fits that description as a titanium buyer. Other examples may include companies that specialize in forgings or castings for a particular material. When companies negotiate their own deals, they can tailor the terms to meet their needs and control their destinies. Of course, how many defense contractors can match or out-perform DNSC will depend to some extent on how large the DNSC aggregated requirements are and what terms DNSC negotiations can achieve.

In addition, defense contractors and subcontractors may have their own strategies for coping with the inevitable cycle of shortages and surpluses in materials industries. They may attempt to time their buys to take advantage of low prices during surpluses and avoid high prices during shortages. They may invest in inventories or implement other hedging techniques. Such approaches may require more flexibility than a DNSC negotiating schedule would allow. For example, DNSC's timing would depend, in part, on when it could accumulate sufficient requirements for multiple programs. Moreover, DNSC might choose to negotiate long-term contracts that span the shortage and surplus periods in the materials cycle. This might be a useful hedging technique, but some contractors might prefer other methods.

Along these lines, DNSC would have to cope with potential free riders. That is, some defense contractors and programs might hope to make their own buys when prices are low and materials are readily available but turn to DNSC when shortages develop and prices spike. The resulting fluctuations in material requirements would weaken DNSC's negotiating leverage and limit opportunities for long-term contracts. Open agreements available to programs on an as-needed basis might well be infeasible.

DNSC presumably could negotiate better terms for DOD if all DOD requirements for a material were included in the resulting contract.[64] Based on the discussion above, this seems impractical assuming program managers voluntarily choose whether or not to participate. It would thus be tempting to make participation mandatory. However, this would produce inferior results for some programs and be extremely risky overall. A more prudent approach would be to evolve the DNSC initiative and attract program participation based on the initiative's demonstrated advantages.

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[64] Inclusion of a high share of DOD requirements would be particularly important to achieve the aggregate stability of requirements needed for the shock absorber option discussed in Section D.3. of this chapter.

2. Defense Contract Issues

Taking advantage of DNSC-negotiated material contracts would require some changes in how DOD contracts with defense producers. In some cases, the implications of such changes could delay or limit the implementation of the DNSC approach. Some examples include:

- Legacy contracts and programs
- Capturing savings under fixed-price defense contracts
- Preserving accountability when materials are GFM

Participation by a program in DNSC material buys normally would not be possible until DOD negotiates new or renewed contracts with defense producers. Where existing contracts exist, for example, required materials may already have been purchased. For mature programs, even though new provisions could be inserted in the next prime contract, it may be costly to disrupt the prime contractor's existing arrangements with subcontractors and material suppliers. As a result, not all programs would be candidates for immediate participation in a DNSC initiative.

Some attention must also be paid to how material cost savings would be passed through to the government. This should not be a problem under a cost-reimbursement contract since a reduction in the cost of the materials purchased by the contractor would translate fairly directly into lower costs reimbursed by the government. Whether the government directs the defense contractor to buy materials under the DNSC contract or the program office provides the materials as GFM, the costs to be reimbursed under the defense contract would automatically be lower. However, under a fixed-price contract, realizing the savings would be more complicated. In cases where defense contractors buy materials under the DNSC contract, expected material costs would have to be taken into account when the overall fixed price is negotiated or perhaps a special provision might be made to pass through material costs. Even when the materials are provided as GFM, the government would have to assess whether the contractor lowered its fixed-price offer accordingly. All of this could be difficult if material costs have low visibility when the defense contract is negotiated or if the DNSC-negotiated price has not yet been established.

A related issue is how the accountability of the defense contractor is affected when the government provides materials as GFM. Problems with the quality or on-time delivery of GFM materials could impair the defense contractor's ability to meet its contractual obligations to the government. The parties would then have to sort out whether any contract performance problems are attributable to the contractor or the government. This kind of ambiguity could increase government costs and offset any savings negotiated by DNSC. There would be similar accountability issues if the

program directs the contractor to buy materials under the DNSC-negotiated contract. Some programs may decline to participate in the DNSC effort if accountability is a major issue or if materials are particularly important to performance under the defense contract.

3 Additional Costs to Government

Potential savings negotiated by DNSC would be offset to some degree by related increases in government costs. Potential examples include:

- Take-or-pay provisions
- Management and coordination costs
- Disruption of existing relationships

DNSC-negotiated contracts will include requirements to purchase certain minimum quantities of materials. The government must buy those quantities even if program requirements are reduced. Purchasing unneeded materials represents an added cost to the government, at least until a use for those materials is found. While this is a general risk for material procurement, it could be exacerbated in DNSC-negotiated contracts if they are more long-term than the typical contract. If DNSC negotiates on behalf of specific programs, those programs would pay for any unneeded materials. However, if DNSC negotiates in anticipation of unidentified program requirements, DNSC would pay.

Government costs for managing this initiative and coordinating requirements would not be trivial for DNSC or the program offices. The program offices would have to gain adequate visibility into material requirements and evaluate which materials in what quantities they should offer up for DNSC negotiations. DNSC would have to solicit requirements for multiple materials from all the program offices, cumulating those requirements to enable timely negotiations to meet the schedules of the program offices. To some extent, DNSC might be required to serve as a communications channel between its vendors and the program offices and defense contractors. DNSC's burden would increase to the extent that it accepted a "shock absorber," or clearinghouse, role to support program offices when their requirements changed.

Also, as discussed above, buying materials through DNSC would disrupt existing supply relationships. Loss of any unique advantages of those relationships could be viewed as an additional cost of the DNSC initiative.

4. Vendor Interest in Negotiations

While DOD uses large quantities of materials, it is not necessarily the largest user of each material it uses. For a number of materials, defense usage represents a relatively small portion of the overall U.S. market. In the case of materials that must be imported, U.S. defense requirements may be a small portion of the overall global market. In these

cases, the size of the material buys DNSC negotiates will not always be sufficient to attract preferential discounts and terms.

Table 4-1, for example, estimates the materials that were used most for defense production in 2008. While the quantities of materials are substantial, they generally do not represent a large share of the total U.S. market for those materials. For half of these materials, defense usage accounts for less than 3.5 percent of overall U.S. demand. An order for 3.5 percent of U.S. demand might seem substantial to a material vendor of moderate size; it would seem less impressive to the largest material producers, whose scale should enable them to produce at the lowest unit costs. Considering that DNSC negotiations would cover only part of defense requirements for a material, it is clear that DNSC will have to work assiduously for a bargain in some cases. On the other hand, for materials like titanium where the defense share is 20 percent, there is a better chance that vendors will bargain hard to get DNSC's business.

Table 4-1. Top Materials Used for Defense Production

Rank	Material	Short Tons per Year	% of U.S. Demand
1	Aluminum Metal	275,220	3
2	Copper	105,626	3
3	Lead	88,465	4
4	Fluorspar acid grade	56,545	8
5	Zinc	51,086	3
6	Rubber (natural)	29,490	2
7	Manganese Ore Chem/Metal Grade	25,042	5
8	Nickel	17,312	6
9	Ferrochromium	9,668	2
10	Chromite Ore	9,631	3
11	Silicon Carbide	8,861	4
12	Titanium (sponge)	8,789	20

5. Foreign Sources

Many of the materials used for defense are sourced substantially or even exclusively from foreign countries. This is a complicating factor and could work to DNSC's disadvantage. For example, the U.S. defense share of global demand is even smaller than its share of U.S. demand and might not impress a large foreign producer that dominates global supply. Moreover, it is not clear how trustworthy an agreement with a material producer in a less developed country would be. For some materials, DNSC might be able to negotiate with large U.S. distributors that import a material from various foreign

sources. However, distributors probably operate with lower profit margins and have less room to shave prices than the producer has. In addition, U.S. restrictions on government procurement from foreign sources would have to be addressed.

E. Implications

It makes sense to explore a larger role for DNSC in the procurement of materials for defense production. DNSC has buying expertise that many program offices may not have. DNSC can negotiate on behalf of multiple programs and thus increase the size of material buys, which should lead to better terms from the material vendor. DNSC might also be in a position to play a shock absorber or clearinghouse role, balancing unexpected changes in requirements across programs.

Key unknowns include how much better DNSC-negotiated terms would be and what requirement quantities the programs would offer up for DNSC negotiations. Continued DNSC experimentation will be needed to resolve these questions.

5. Understanding Operational Impacts of Material Supply Disruptions

A 2008 survey by OSD of material availability concerns among the Services identified a number of problems. IDA was asked to start assessing the potential adverse effects such production/availability problems could have on DOD readiness, operations, and battlefield performance. The most vivid example that OSD officials have related to IDA thus far occurred several years ago and involved specialty (armor) steels for Mine-Resistant Ambush Protected vehicles (MRAPs).[65] Key elements of that case are summarized below.

In order to provide U.S. warfighters in Iraq with equipment that could reduce U.S. casualties from improvised explosive devices (IEDs), in May 2007 the U.S. Joint Requirements Oversight Council (JROC) validated a requirement for 7,774 MRAPs and followed with an interim decision in July 2007 to produce as many MRAPs as possible by the end of the calendar year. At the beginning of 2007, however, the United States had an industrial capacity to build fewer than ten MRAPs per month. During 2007, the DOD took a set of extraordinary measures to increase U.S. industrial capacity to produce MRAPs. According to DOD officials, through such measures the DOD was able to produce 154 MRAPs in July 2007. By year's end, that capacity approached 1,000 per month.[66]

A key bottleneck in MRAP production early in 2007 was U.S. ability to produce armor steel plate and thin-gauge, quenched, and tempered steel. There are several different varieties of MRAP, but most vehicles contain between 5,000 and 8,000 pounds of armor steel. To solve this problem, in June 2007 the Secretary of Defense approved a "DX" (DPAS) rating for the MRAP program, giving it the highest priority for access to materials in the United States. DOD also used legal waiver processes to tap both

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[65] Several other industrial constraints, like tire, axle and prime contractor capacities, also limited MRAP production. See generally, Defense Contract Management Agency, *Mine Resistant Ambush Protected (MRAP) Vehicle Industrial Capacity Assessment Update Supporting DUSD Industrial Policy,* September 10, 2007.

[66] Testimony of the Honorable John J. Young, Jr., Director, Defense Research and Engineering, Mr. Bill Greenwalt, Deputy Under Secretary of Defense for Industrial Policy, and Captain Cloyes Hoover, U.S. Navy Commanding Officer, Space and Naval Warfare System Center, Charleston, before the Subcommittees on Seapower and Expeditionary Forces and Air and Land Forces of the House Armed Services Committee, November 8, 2007, pp. 4-5.

additional domestic sources as well as reliable foreign sources. As a result, DOD was able to obtain access to enough armor steel plate and thin-gauge, quenched, and tempered steel by the end of 2007 to meet essentially all of DOD's MRAP-related demands.[67]

The impact of armor steel production constraints on MRAP production is illustrated in Figure 5-1. The graph is an estimate prepared by DOD in late October 2007 showing how increasing steel (quenched and tempered (Q&T)) production, from capacities that had been demonstrated to maximum possible capacities, would allow DOD to meet its MRAP requirements.[68] The dark blue line projects MRAP production in vehicles per month, unconstrained by steel production capacities. The yellow line projects what MRAP production rates would have been had steel production not been increased. The pink line projects MRAP production capacities given then-projected increases in steel production. The graph showed that steel production constraints could have delayed the production of all required MRAPs by about a year. However, DOD's efforts to increase steel production were projected to (and did) eliminate those delays, such that steel production limits did not delay the fulfillment of DOD requirements for MRAPs.

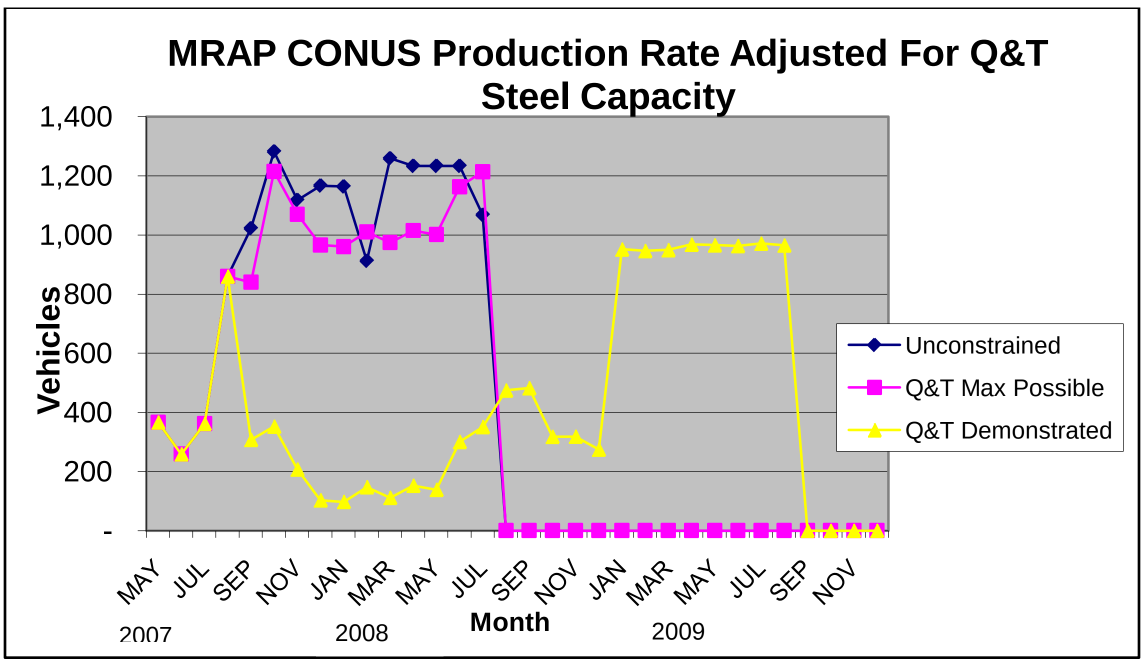

Figure 5-1. MRAP CONUS Production Rate

67 Ibid., pp. 6-9.

68 *DOD Armor and Steel Requirements – Charts* (MS Excel), October 26, 2007, provided by Defense Contract Management Agency in March 2010.

One important lesson of the MRAP case is that DOD can, under some circumstances, and with enough priority assigned to a system, quickly increase U.S. and trusted foreign nations' capacity to produce key materials for U.S. military equipment, thus mitigating battlefield impacts of equipment shortages. By the accounts IDA has seen, having more MRAPs available in Iraq sooner rather than later was instrumental in reducing U.S. battlefield damage from IEDs there.[69]

To prepare for broader-scale crises and material supply disruption possibilities in the future, DNSC and the DOD may want to consider assessing well beforehand the prospects and pay-offs of using any and all of the kinds of tools that the DOD employed with MRAP in order to mitigate potential material shortfalls for critical military and other national security equipment.

Consider, for example, what operational problems could arise for DOD, or for DoE, in obtaining needed parts containing rare earth magnets, if PRC production and supply to the United States were to be disrupted. Production of which critical security and/or energy grid items would be disrupted? How severe could the consequences be? What can and should be done now to mitigate such risks?

One important, practical next step to answer these questions would be for the DNSC/SMSP to query the Services and other Federal departments systematically as to the forms and quantities of rare-earth-containing parts that they now use in their high-priority systems, and to obtain information as to where they obtain such parts. A related next step would be to survey those parts vendors as to where they obtain the rare-earth components for those parts. A third step would be to determine what the capabilities are of various existing vendors, and various potential vendors, and then to assess the potential of those shops to accelerate/expand their production of key items.[70]

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69 In a memorandum to the Chairman of the Joint Chiefs of Staff dated 1 March 2007, General James Conway, Commandant of the Marine Corps wrote: "The MRAP vehicle has a dramatically better record of preventing fatal and serious injuries from attacks by IEDs. The Commander of Multinational Force West estimates that the use of MRAP could reduce the casualties in vehicles due to IED attacks by as much as 80 percent." By April 2007 there had been 300 IED attacks in Iraq against the MRAP since it was introduced in 2006, and not one death in those attacks. According to Marine Corps BG John Allen, Deputy Commander of Coalition Forces in Anbar Province, there had been an average of less than one injured Marine per attack on the vehicles, while attacks on other types of vehicles caused more than two casualties per attack, including deaths. By early 2007, over 3,300 U.S. troops had been killed in Iraq, and as many as 70 percent of those casualties had come as a result of improvised explosive devices, IEDs." "Mine Resistant Ambush Protected (MRAP) Vehicle Program," Globalsecurity.org, page last modified August 27, 2009, available at http://www.globalsecurity.org/military/systems/ground/mrap.htm: accessed June 10, 2010.

70 IDA understands that OSD (Industrial Policy) has recently commissioned an initial study of this sort by DCMA (IAC), and that the results are due in September, 2010. A repository to house such information for ready, DOD access for additional analysis would be useful. Along these lines, a prototype framework that might be able to handle and assess data of this sort for assessments was developed some years back for the Joint Staff (J4), entitled JIMPP--the Vendor Level Module (see

A more comprehensive and systematic understanding of the adverse impacts of potential S&CM supply disruptions will hinge upon a much more in-depth analysis than has been possible under this particular task for DNSC.[71] But the MRAP case can provide a very useful example of what can be done to ramp-up production of key materials under crisis circumstances. While the MRAP case will not be an appropriate template for all such problems, it can be an instructive place to think through combinations of tools that could work together in an integrated SMSP.

IDA Document D-1338). It might be feasible to resuscitate the JIMPP VLM to hold and, more importantly, to analyze data on key systems, components and S&CMs for DOD.

[71] Clearly sorting out the relative effects of the various prioritization and supply-enhancing initiatives that the DOD took even in the MRAP case will likely require additional analyses. MRAP production rates did increase after the Secretary approved a DX rating for the program on June 1, 2007. However it is difficult to ascertain the precise impact of that decision because of the other efforts made before and after to increase production rates (e.g., physical expansions, product and material specification changes, loosening of supplier eligibility rules). One steel producer stated that the DX rating reduced the lead time for armor plate production from 12 to 6 weeks. But an MRAP prime contractor complained that the DX rating was not helpful because all the MRAP contractors ended up competing with each other for the same resources. Nevertheless, the total impact of the measures taken to increase steel production did provide enough material to meet DOD's needs for MRAP. Sources: Defense Contract Management Agency, "Mine Resistant Ambush Protected (MRAP) Vehicle Industrial Capability Assessment Update," September 10, 2007; Defense Contract Management Agency, "Mine Resistant Ambush Protected (MRAP) Vehicle Impact Study," May 30, 2008; Testimony of the Honorable John J. Young, Jr., Director, Defense Research and Engineering, Mr. Bill Greenwalt, Deputy Under Secretary of Defense for Industrial Policy, and Captain Cloyes Hoover, U.S. Navy Commanding Officer, Space and Naval Warfare System Center, Charleston, before the Subcommittees on Seapower and Expeditionary Forces and Air and Land Forces of the House Armed Services Committee, November 8, 2007.

6. From the National Defense Stockpile (NDS) Toward an SMSP

Traditional government stockpiling—like the NDS—is not the only way to hedge against potential material shortfalls. The SMSP is considering various approaches to material security. In that spirit, IDA offers several thoughts for DOD and the U.S. Government on how to assess and build the most cost-effective ways to address such material availability challenges and risks in the years ahead.

Overall, both demand-side and supply-side risk mitigation approaches should be considered by DOD and the U.S. Government generally in strategic planning with regard to S&CMs. On the demand side, for example, the government may want to assess the possible reductions in shortfalls that could be obtained by one or more of the following initiatives: substitution possibilities, deferral of some of the demands in the planning scenario, and having panels of subject matter experts (SMEs) categorize estimated shortfalls into more and less essential demands. On the supply side, it could be helpful to understand what shortfall mitigation effects might be obtained by pre-arranging "surge" contracts with domestic and other very reliable suppliers, so that extra production might be obtained by the U.S. Government more quickly than is now likely in the event of an emergency. The MRAP case mentioned in Chapter Five may be a model to consider for its applicability in other cases. What are the relative costs of and payoffs from these various possibilities?

One demand-side assessment that might be considered would make the broad alternative assumption that in the first year of the 2011 Requirements Planning Case it may be feasible to substitute various platinum group metals for each other in some essential civilian sector applications. What impact might such substitution possibilities, where feasible, have upon the estimated shortfalls in IBC1?[72]

[72] In IBC1, five platinum group metals (PGMs) were examined. Some of them exhibited significant shortfalls, but for the group of PGMs as a whole, available supply (after all decrements) exceeded demand. Even in the first year, the available supply was about 35 percent more than demand. This suggests that substitution, if feasible, might ameliorate some shortfalls.

A second demand-side excursion would assess the broad alternative assumption that it is feasible to achieve civilian sector austerity levels more quickly than in IBC1. What impact might such a policy have upon the economy? Upon IBC1 shortfalls?[73]

On the supply side, one excursion would make the broad alternative assumption that it would be feasible to achieve full production capability in the United States within six months, rather than the more conservative IBC1 assumption of full ramp-up time of one year. What impact would that more aggressive assumption have upon the IBC1 shortfalls?[74] What surge contingency contracts would need to be in place to plausibly enable such an expedited production capability? What would they cost?

A second supply-side excursion that could be instructive would explore the broad alternative assumption that it would be feasible for DOD to obtain larger-than-normal market share amounts of materials from fully reliable foreign suppliers if there were contingency contract arrangements pre-established with them. What impact would such surge production arrangements have upon the IBC1 shortfalls?[75] What would it cost to establish and maintain such contracts and relationships?

A third, and also potentially helpful, supply-side excursion that might be conducted, could estimate the impact that having specific new domestic refining/processing capabilities could have upon the IBC1 shortfalls for important categories of materials, such as for the rare earths.[76]

Focused analyses of some of these alternatives could be conducted within the context of the 2011 NDS/SMSP Requirements Report. The demand- and supply-side excursions mentioned above are hardly intended to exhaust the range of options that DOD and the USG generally may want to examine in the new SMSP program. Rather, they may suggest some ways in which systematic and regular assessments of a variety of such cases could contribute to a structured and rational approach to S&CM risk management and risk mitigation planning for DOD and the USG.

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73 Test runs were done with "maximal" austerity: the reduction factors (Appendix B) that were applied to civilian demand in years two through four of the IBC1 case were applied in all years of the test run. Shortfalls were about 92 percent of those in the IBC1 case.

74 Test runs for standard materials indicate that implementing this assumption could reduce the shortfall amount by about 30 percent from the IBC1 result.

75 Test results on this factor are inconclusive so far, but seem to indicate that the timing of the surge makes a difference. It is straightforward to do this kind of sensitivity analysis using the models.

76 One test run indicated that implementing such domestic capabilities could reduce rare earth shortfalls by over 50 percent from the IBC1 case.

A. Recommendations

Finally, IDA offers several recommendations for next steps that the sponsor and DOD may want to consider in building requirements assessment and risk management strategies for key strategic and critical materials in the years ahead.

IDA recommends that DOD consider conducting several additional assessments as it designs and implements its new, and significantly reconfigured, NDS program, now called the Strategic Materials Security Program (SMSP). Assessments could include the following:

Assess Additional Scenarios and Materials

1. Explore and track more systematically a wider range of plausible scenarios than the NDS normally considers;
2. Study more materials (such as more rare earths);

Conduct More Detailed Supply-Chain Analyses

3. Conduct more in-depth analyses of weapon-specific supply-chains;

Conduct More Risk and Risk-Mitigation Analyses

4. Carry out risk analyses of the likelihood and operational- as well as national-level consequences of various NDS/SMSP planning cases;
5. Analyze the risk-mitigation effects and costs of various pre-crisis, contingency "surge" contract arrangements with U.S. and closely-allied vendors;
6. Conduct regular form and grade studies of various "rolling inventory" strategies (inventories of materials subsidized to be held at and used (rolled over) by DOD contractors as they produce weapons);
7. Analyze ways to incentivize private industry to revitalize supply-chains, e.g., through loan guarantees and multi-year contracts to buy their output;
8. Study material substitution strategies in DOD and the civilian sector;

Assess Purchasing Efficiencies

9. Analyze ways to promote purchasing efficiencies for DOD and the USG in the S&C materials area generally using DNSC's contracting expertise.

B. Summary

The chapters of this paper have addressed different aspects of identifying, assessing, and mitigating risks to the supply of strategic and critical materials. Chapters One and Two show how the current methodology for identifying material shortfalls can illuminate the effect of changes in material supply and demand. That is, the shortfalls in the Interim Base Case are considerably larger than shortfalls shown in previous reports to the Congress, because the underlying data and assumptions about demand and available supply have changed. Chapter Two also identifies a number of factors in the modeling process that can be adjusted to perform numerous sensitivity analyses. Chapter Three demonstrates that materials hitherto unassessed can be analyzed: supply and demand data for a number of new materials have been obtained, and the existing shortfall assessment methodology has been used to determine the risk that supply shortfalls will occur for them. Chapter Four discusses a number of ways to mitigate potential material supply shortfalls that do not involved stockpiling, and Chapter Five illustrates the illustrates the interrelationship between military readiness, weapon manufacturing, and the supply of strategic materials.

All of these aspects can play a role in the management of the Strategic Materials Security Program. Continued analysis of strategic and critical materials, from all of the various perspectives taken in this report, will help ensure that the United States has adequate supplies of strategic and critical materials to meet its needs.

Appendix A.
An Overview of Models Used in the National Defense Stockpile (NDS) Requirements Process

The Department of Defense (DOD) tasked IDA to design an analysis process for determining NDS requirements. The three-step process that IDA proposed, and which DOD subsequently adopted, is intended to provide DOD with clear, auditable estimates of potential shortfalls of major non-fuel strategic and critical materials (S&CMs) in the context of an official (classified) planning scenario, a scenario newly crafted by DOD in each biennial reporting cycle to be consistent with the terms of the Stock Piling Act.[77] The first two steps in the requirements process aim at building estimates of the time-phased, essential U.S. defense *and* civilian sector demands for S&CMs in the context of the mandated planning scenario. The third step involves both estimating the time-phased supply of these materials in that scenario (not counting any NDS inventories) as well as comparing those non-NDS supplies with the time-phased demands. If any gaps ("shortfalls") are identified, then existing NDS inventories are considered. If existing NDS inventories of a material are insufficient to cover (eliminate) the shortfall, then a *shortage* for that material is said to exist in the NDS. If the NDS inventory for that material suffices to cover the shortfall, there is no shortage. If inventories exceed shortfalls, such an overage is considered to be a "surplus." Figure A-1 provides an overview of the three steps.

[77] Key provisions of The Stock Piling Act as amended are: "The Secretary shall base the national emergency planning assumptions on: (1) a military conflict scenario consistent with the scenario used by the Secretary in budgeting and defense planning purposes….(2) The losses anticipated from enemy action; (3) The military, industrial, and essential civilian requirements to support the national emergency. The stockpile requirements shall be based on those strategic and critical materials necessary for the United States to replenish or replace, within three years of the end of the military conflict scenario required under subsection (b), all munitions, combat support items, and weapons systems that would be required after such a military conflict."

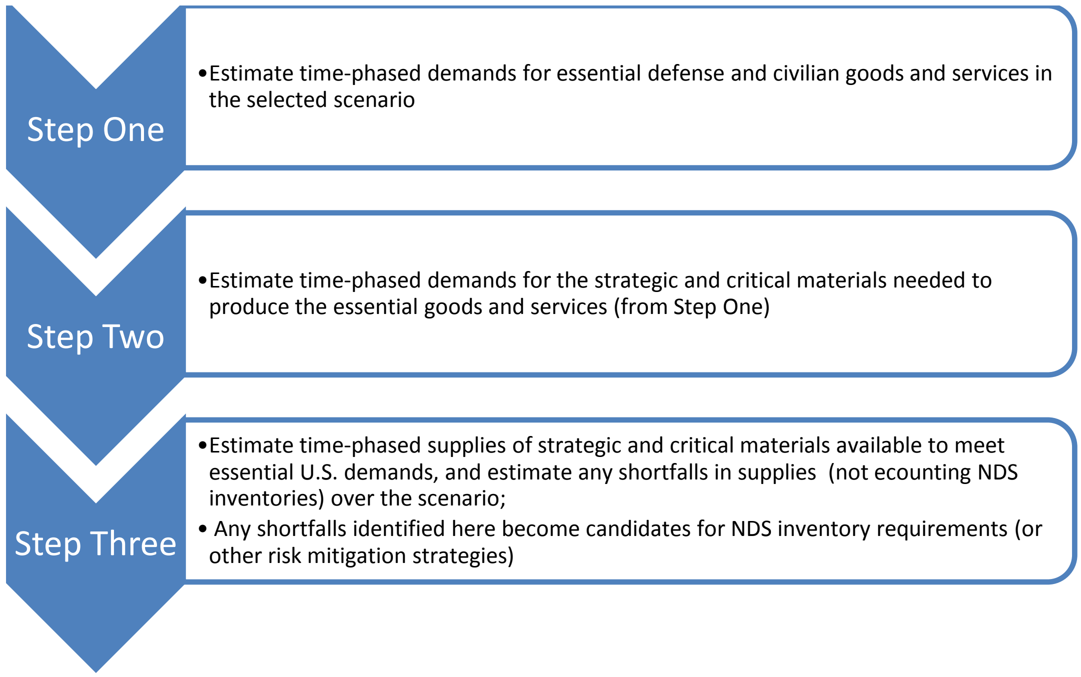

Figure A-1. A Three-step NDS Requirements Process

The three-step requirements process uses a suite of models. These models are the following: the Long-term Interindustry Forecasting Tool (LIFT) and the Interindustry Large-scale Integrated and Dynamic (ILIAD) econometric models, the Forces Mobilization (FORCEMOB) model, and the Stockpile Sizing model (SSM). In addition, the NDS requirements process employs a number of auxiliary computer programs to perform custom estimates and output reports. A brief description of the main models is provided in this appendix. Detailed documentation on these models is provided in IDA Paper P-2867 (SSM), IDA Paper P-2953 (FORCEMOB), and INFORUM documentation (LIFT and ILIAD).

Figure A-2 offers a flowchart depiction of the elements and models involved in Step One. The following paragraphs present an overview of the models used in the entire process.

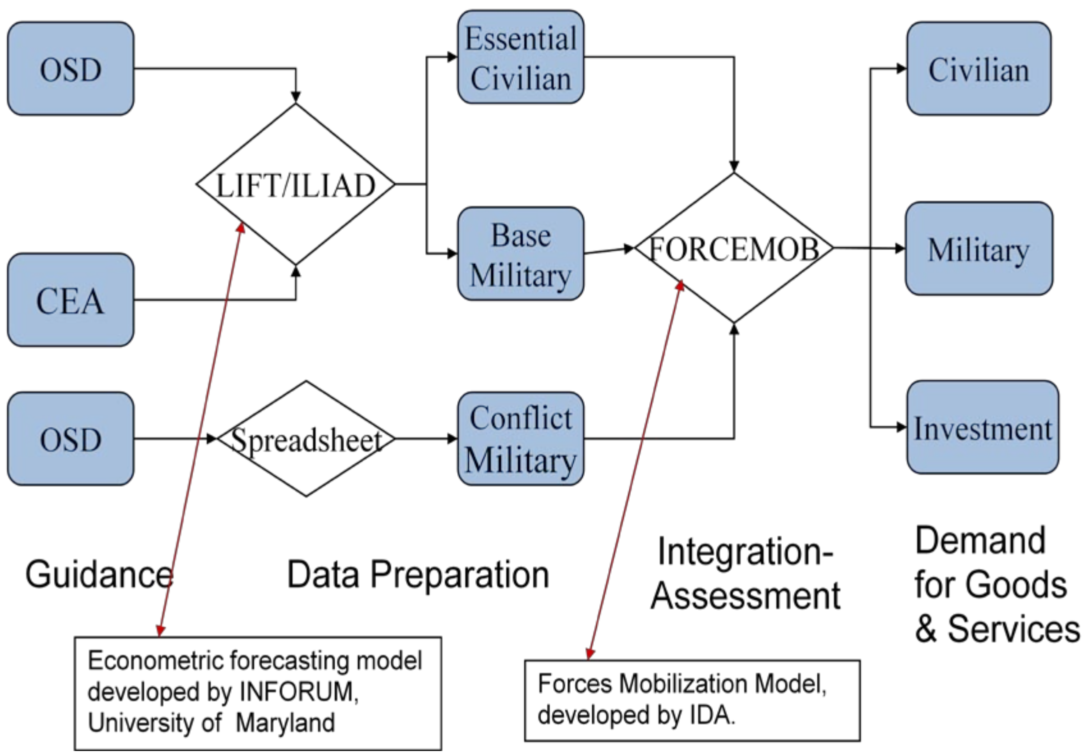

Figure A-2. Summary Flowchart for Step One

LIFT and ILIAD

LIFT and ILIAD are long-range economic forecasting models developed by INFORUM (Interindustry Forecasting at the University of Maryland). They have the unique capability to link high-level measures of economic performance to demands for particular products and requirements for production by particular industries. IDA uses these models to translate the Council of Economic Advisors' (CEA) long-range economic forecast into output requirements for the specific industry sectors that buy and utilize SCMs.

LIFT is a macroeconomic model that includes an input-output matrix showing what ninety-seven production sectors must buy from one another in order to make their products. LIFT forecasts GDP and its major components and then derives spending demands for ninety-two consumer products and services, fifty-six types of production equipment, twenty-five types of construction, and twenty-five types of defense spending. LIFT then calculates what each of the ninety-seven production sectors must produce in order to satisfy the spending demands. The ILIAD model, which includes an input-

output matrix for 360 production sectors, then calculates output requirements for each of those 360 industries. These results are projected in detail more than ten years into the future.

IDA calibrates the LIFT and ILIAD models to match the CEA macroeconomic forecast and project the industry output requirements. IDA modifies these results to reflect DOD specifications of what civilian demands should be considered essential for stockpile purposes. The rich detail in these models enables DOD to discriminate among various types of demands in specifying what is essential. The input-output matrices in these models are also used to determine additional output requirements generated by the assumed military conflict.

FORCEMOB

FORCEMOB stands for Forces Mobilization Model, and part of it does indeed deal with time-phased force requirements. But its overall objective is to compute and organize the demands for industrial output, i.e., demands for goods and services. FORCEMOB has three main parts:

1. Computation of the industrial output needed to manufacture the weapons associated with the conflict scenario;
2. Adjustment of the industry-related quantities computed by the LIFT and ILIAD models; and,
3. Computation of extraordinary investment demand.

All demands are time phased streams. FORCEMOB keeps track of time by month; its outputs are eventually aggregated into quarterly or annual data. The three parts of FORCEMOB are discussed in the three paragraphs below.

1. A scenario for a military situation is specified. This scenario might involve a long mobilization period culminating in conflict. Or, as in recent National Defense Stockpile studies, it might be a regeneration scenario, in which weapons and supplies lost in a conflict are rebuilt over a period of time. By suitably setting certain inputs, it is also possible to model some kind of ongoing, steady-state demand for weapons, or to model a peacetime case with no extraordinary total military demand. This military situation gives rise to an extraordinary military demand for weapons, ammunition, and combat support material. The time phased demands for these force requirements are input to FORCEMOB. FORCEMOB then applies a data set that determines the industrial outputs required to produce these military items. The manufacture of weapons occurs over a lead time (that can vary by weapon type), and some amount of industrial

contribution is required at each month of the lead time. The result is a time-phased set of industrial demands.

2. The LIFT and ILIAD models have computed the essential civilian demands (which might include requirements for repairing damage caused by attacks on the homeland) and base military demands. LIFT and ILIAD have also computed imports, exports, and supply (output). This information is read into FORCEMOB. FORCEMOB can then apply user-supplied adjustment factors to these values that are in concordance with specific characteristics of the conflict scenario. For example, exports might be decremented because more industrial output is needed domestically during the conflict. Imports might be decremented to reflect unreliability of foreign countries affected by the conflict.
3. The extraordinary military demand might create an imbalance in the economy, and existing industrial output (plus net imports) might be insufficient to cover the increased demand. If new plants and facilities are built, the additional output they produce might ameliorate some or all of the excess industrial demand. However, the goods and services required to build these plants and facilities become an additional source of demand, referred to as the extraordinary investment demand. FORCEMOB computes the extraordinary investment demand, using economic data on the industrial contributions required to build new facilities.

FORCEMOB can produce many informatory reports about various subsets of its data and output. The main output report presents demands on industry, organized by industry and year or quarter, for each of the following categories:

- Military demand associated with the conflict scenario
- Base military demand
- Essential civilian demand
- Extraordinary investment demand
- Imports
- Exports

A demand value is shown for each combination of industry, time period, and category. This report is read by the computer programs that deal with Step Two of the requirements process.

Computation of Material Demand

A few words about the computer programs used in Step Two, the computation of the material demand, are in order. There are two programs. Both programs use the FORCEMOB output, but in different ways. The first program is used for standard materials, i.e., materials that have Material Consumption Ratios. The MCRs specify the

amounts of materials required to manufacture a (billion) dollar's worth of industrial output (for each given industry). The program applies the MCRs to the industrial demands to determine material demands. A separate computation is performed for each industry sector; the results are then summed (over industry, for each material in turn) to determine total material demand. In the process, conflict military and base military demands are added together into a single military category, and net exports are added to civilian demand. If the FORCEMOB data are quarterly, they are aggregated into annual data.

The second computer program implements the proxy MCR approach discussed in Appendix C. It is used for materials for which MCRs are not available, such as the specialty and new materials.

The Stockpile Sizing Model

The Stockpile Sizing Model[78] implements Step Three of the NDS requirements process. The objective of the SSM is to determine material shortfalls: demands that cannot be met by anticipated supplies. The material demands computed in Step Two are read into the model. The following procedure is performed separately for each material under consideration.

1. Start with projected peacetime material supply amounts (measured in mass units, such as tons), by country of origin (including the U.S.) and year of the scenario. This information is read into the model.
2. Depending on user preference, U.S. supply might or might not include secondary production (i.e., recycling) and might or might not include concerted programs, i.e., non-current production facilities that could be activated or developed if sufficient funds were available.
3. Determine each foreign country's supply use category. That is, can its supply be used to satisfy all categories of material demand (defense, extraordinary investment, and civilian), or to satisfy civilian demand only? (The model allows several options for doing this.)
4. For foreign supplies, apply decrement and delay factors (war damage, shipping losses, ability degradation, anti-U.S. orientation, foreign competition [i.e., market share]) to determine the amounts of available foreign supply, by year and country of origin. These factors, which are input to the computer program, model the effects of the underlying conflict scenario on material supply. (The SSM treats anti-U.S. sentiment as causing delay in the arrival of supply to the U.S.. This can model a situation where the U.S. might need to obtain supply from an

[78] The Stockpile Sizing Model is often referred to as the Stockpile Sizing Module, because at one point it was a module in a suite of models.

international broker, rather than directly from an unfriendly country. The U.S. will eventually obtain the supply, but there might be a delay time to get international markets to work.)

5. For each combination of use category and year, take the sum over countries of the available foreign supply amounts, to get a total available foreign supply for that use category and year. If useable foreign supply is to be capped at a multiple of current material imports, apply that cap.
6. Compare material supplies with material demands and determine shortfalls. Supply available in a given year can offset demand in that year or later, but not demand in earlier years. Constraints on category of demand (item 3, above) are also taken into account. The procedure attempts to satisfy defense demands before civilian, and to use domestic supply in preference to foreign.

Depending on the particulars of the scenario, the initial material supply might correspond to estimated future production or estimated future capacity. There is an argument that a material should not be stockpiled if it can be obtained merely by working a facility to capacity. In a national emergency, funds for working a facility to capacity are assumed to be available. For peacetime scenarios, it might be appropriate to use estimates of production, rather than capacity. It also might be advisable to adjust the first year value to be consistent with some kind of ramp-up toward full capacity.

Figure A-3 depicts Step 3 of the NDS requirements process.

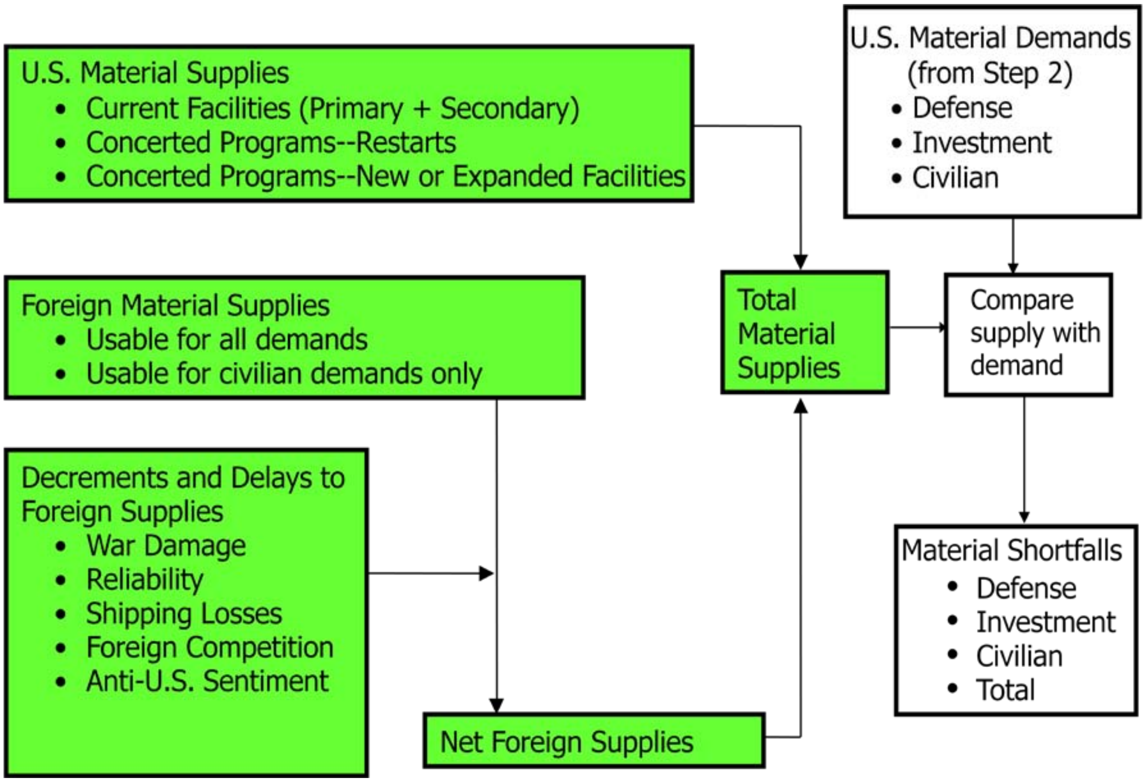

Figure A-3. Step Three – Material Supply and Demand Comparison

Appendix B.
Essential Civilian Needs and the National Defense Stockpile

Introduction

The statute governing the National Defense Stockpile (NDS) requires the Secretary of Defense to provide Congress the planning assumptions underlying the Secretary's recommendations on stockpile requirements, including (inter alia):[79]

> "(4) The military, industrial, and essential civilian requirements to support the national emergency"
>
> "(7) Civilian austerity measures required during the mobilization period and military conflict"

Essential civilian needs are thus considered explicitly in the DOD NDS requirements process that identifies potential needs to stockpile strategic and critical materials (SCMs). The following discussion describes how civilian needs are treated in the requirements process and identifies alternative approaches that could be used. While the present approach seems sensible, it embodies a number of legacy policy choices that DOD may want to reassess. The alternatives are designed to facilitate such a reassessment.

A. Background

During a national emergency, civilian needs will inevitably compete with defense needs for access to scarce national resources, including the available supply of SCMs. Civilian authorities will support DOD in obtaining the resources needed to meet defense requirements. For example, the Department of Commerce will employ its authorities under the Defense Priorities and Allocations System (DPAS) for this purpose.[80]

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[79] See U.S. Code 50, § 98h-5.

[80] The Director of the Federal Emergency Management Agency (FEMA) and the Secretaries of Energy, Agriculture, Health and Human Services, and Transportation will also have priorities and allocations responsibilities. See William J. Clinton, "National Defense Industrial Resources Preparedness," Executive Order 12919, June 3, 1994.

However, as shortages develop, civilian needs deemed essential may also be at risk. Civilian authorities can be expected to balance military and essential civilian needs in controlling the distribution of SCMs. Indeed, as suggested by the legislation cited above, the President may authorize the release of NDS inventories to meet certain essential civilian needs. As a result, requirements to stockpile SCMs cannot be based on military needs alone but must also reflect potential shortfalls in meeting essential civilian requirements. If stockpile inventories are insufficient, both military and essential civilian needs may suffer.

During World War II, the War Production Board (WPB) played a key role in administering contract preference rating systems and controlling the distribution of scarce raw materials such as steel, aluminum, and copper.[81] As a civilian authority, the WPB was responsible for supporting military requirements but also for ensuring that the most essential civilian requirements were met as well. When necessary, the WPB itself assigned preference ratings to civilian contracts and allocated raw materials needed for the production of civilian goods. The War Department objected strenuously when the WPB balancing act caused military requirements to go unmet.

But what civilian needs should be considered essential? The answer depends very much on circumstances at the time including especially how serious the national emergency is and how severe SCM shortages are. The stockpile statute itself does not provide guidance on what civilian needs should be considered essential.[82] During World War II, the U.S. Government considered the use of half of the country's automobiles to be "nonessential" and limited gasoline sales for them to four gallons per week. More generous limits were established for industrial war workers, truck drivers, and farmers but also for physicians, ministers, and members of Congress.[83] This suggests that essential uses included both contributions to the war effort and some amount of support for the civilian population. The WPB itself included industry committees to help determine essential civilian needs.

More recently, during the 1990s, the United Nations (UN) oversaw an oil-for-food program that allowed Saddam Hussein's Iraq to export certain amounts of oil for the purpose of paying for civilian imports. Permitted imports included "…medicine, health

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81 The World War II experience is discussed in John D. Millet, *The Organization and Role of the Army Service Forces*, Center of Military History, United States Army, 1998, and Alan L. Gropman, *Mobilizing U.S. Industry in World War II: Myth and Reality*, Institute for National Strategic Studies, McNair Paper Number 50, August, 1996.

82 Essential civilian needs are also referenced but not defined in statutes dealing with the Federal Emergency Management Agency (FEMA) and the Defense Production Act (DPA). See U.S. Code 42 (2010), §5195 for the former and U.S. Code 50 (2010)-Appendix, §2153 for the latter.

83 See the discussion at Ames Historical Society website, available at www.ameshistoricalsociety.org/exhibits/events/rationing.htm: accessed June 10, 2010.

supplies, foodstuffs, and materials and supplies for essential civilian needs (hereinafter humanitarian supplies)….”[84] The UN did not define “essential,” but established a committee to evaluate specific requests. Permitted items included repair parts for the rehabilitation of infrastructure needed for humanitarian purposes. The resulting limitations on civilian imports were part of the punitive sanctions imposed on Iraq to exert pressure over weapons of mass destruction and human rights.[85]

The Fourth Geneva Convention provides another point of reference.[86] It outlines the responsibilities of a combatant power toward civilians that come under its control in occupied territories. The occupier is required to ensure the provision of food and medical supplies to the protected population. The Convention also addresses the need for public utility services, food, shelter, clothing, transportation, medical facilities, public health, education, religion, and orderly government. Presumably, the U.S. public would expect more than these bare necessities during a national emergency in this country.

B. Current Structure for Specifying Essential Demand

In the DOD NDS requirements process, the projected civilian final demands for goods and services are reduced to eliminate spending that is considered nonessential. Requirements for SCMs are then calculated based on the decremented demands for goods and services. Reduction factors specify the percentage of civilian spending that is considered nonessential for each of seventy-eight types of personal consumption and thirty-one types of construction. These spending categories reflect the level of detail available in the simulation models used for the study.[87] Examples of the factors are shown on Table B-1. The full set of factors is shown in Section E (Table B-2) of this Appendix.[88]

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84 See *United Nations and Iraq, Memorandum of Understanding on the Implementation of Security Council Resolution 986* (1995) (with Annexes), Signed at New York on May 20, 1996, No. I-32851, available at http://untreaty.un.org/unts/120001_144071/25/7/00020981.pdf: accessed June 10, 2010.

85 Some sources claim that civilian imports were reduced by two-thirds compared to their prior levels. See for example “CPC – A Partial List of Items Banned from Import into Iraq by UN Imposed Economic Sanctions,” California Institute of Technology website, available at http://www.ugcs.caltech.edu/~progress/flyers/banned.html: accessed June 10, 2010.

86 See “Geneva Convention IV Relative to the Protection of Civilian Persons in Time of War, August 12, 1949,” at the *Reference Guide to the Geneva Conventions*, Society of Professional Journalists, available at http://www.genevaconventions.org: accessed June 10, 2010.

87 The DOD NDS requirements process uses the LIFT and ILIAD input-output models developed by INFORUM. For example, these models are used to translate nonessential spending decrements into reductions in output requirements for particular industries.

88 A different set of control factors specifies percentage reductions in exports for each industry sector.

Table B-1. Reduction Factors for Nonessential Spending (Excerpt from Table B-2)

Personal Consumption Expenditure Categories		Conflict Year	Regeneration		
			Year 1	Year 2	Year 3
1	New Cars	50.0	75.0	75.0	75.0
2	Used Cars[89]	25.0	50.0	50.0	50.0
3	New & Used Trucks	25.0	50.0	50.0	50.0
4	Tires & Tubes	25.0	50.0	50.0	50.0
5	Auto Accessories & Parts	15.0	15.0	15.0	15.0
6	Furniture, Mattresses, Bedsprings	25.0	50.0	50.0	50.0
7	Kitchen, Household Appliances	25.0	50.0	50.0	50.0
8	China, Glassware, Tableware, Utensils	25.0	50.0	50.0	50.0

The study assumes a four-year Base Case Scenario, with combat at the beginning and replacement of items consumed or lost in combat by the end. Nonessential spending decrements are phased in, with more modest reductions in the first year. This allows some time for shortages to develop and for the various sectors to adjust.[90] The practical implementation of spending decrements during an actual contingency is discussed in section D of this Appendix.

The detailed specification of reduction factors was established by DOD in the 1990s in consultation with a civilian interagency working group. The rationale for that specification is not documented but can be inferred from the spending patterns it sanctions. Requirements that are deemed essential can be grouped according to the following purposes:

- Procuring goods and services for defense;
- Sustaining supporting industries;
- Maintaining national economic strength;
- Providing government services;
- Maintaining an adequate civilian standard of living; and
- Recovering from an attack on the U.S. homeland.

[89] Used car sales are decremented to account for their indirect influence on demands for gasoline, parts, and tires.

[90] Material shortfalls may emerge only gradually and the necessary spending decrements may not be apparent when the emergency begins.

Defense Procurement

All defense requirements are considered essential. This includes regular ongoing defense spending as well as additional requirements generated by the emergency, such as the replacement of items expended or damaged in combat. Both the end items delivered to DOD and the intermediate goods and services necessary for defense production are considered essential.

Supporting Industries

Investment in equipment for key industries that support defense production is considered essential. These include the industries that produce defense goods and services as well as the sectors that produce inputs such as metallic parts, electronic components, and engineering services. Also included are industries that provide infrastructure services such as power, communication, and transportation.[91] The continued health of these sectors, including the ability to fund innovation and expand capacity to preclude shortages, strengthens their utility for defense purposes.[92]

Investment in new construction for these sectors is deemed essential only in part. For most industrial sectors, roughly half of new construction is considered essential. That should be more than enough to ensure that industrial construction needs vital to defense can be completed. For some particularly important sectors, all new construction is considered essential. These sectors include those providing infrastructure services as well as farm and mining sectors.

National Economic Strength

Activities that contribute to the preservation and growth of a strong U.S. economy are considered essential in part. President Barack Obama recently reminded U.S. citizens of[93]

> …the connection between our national security and our economy…Our prosperity provides a foundation for our power. It pays for our military. It underwrites our diplomacy. It taps the potential of our people, and allows investment in new industry. And it will allow us to compete in this century as successfully as we did in the last.

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91 Services provided by infrastructure sectors may also be considered essential for the purpose of maintaining an adequate standard of living.

92 For example, with reference to the Defense Production Act, Section 102 of U.S. Code 50a, § 2153 declares that the "United States must have an industrial and technology base capable of meeting national defense requirements, and capable of contributing to the technological superiority of its defense equipment."

93 See Barack Obama, "Remarks by the President in Address to the Nation on the Way Forward in Afghanistan and Pakistan, December 1, 2009, available at http://www.whitehouse.gov/briefing-room/speeches-and-remarks: accessed June 10, 2010.

In this spirit, economic sectors that offer little or no support to defense production may nevertheless contribute to present and future national security. Investment in productive equipment for these sectors is considered essential in the DOD NDS requirements process. Generally, about half of the investment in new construction for these sectors is also considered essential.

Exports represent another activity important to national economic strength. Export sales help sustain U.S. industries, provide a balance to U.S. expenditures on imports, and enable the U.S. to support and influence allies. However, exports also consume resources including SCMs. For these reasons, most exports are considered essential but a significant portion (15 to 25 percent) is decremented as nonessential.[94]

Government Services

All government spending is considered essential. Government services support the war effort directly and indirectly, maintain economic stability and the standard of living, and ensure law and order. For these reasons, government spending at the national, state, and local levels is deemed essential, including government investment in equipment and new construction.

Standard of Living

Some degree of civilian austerity is deemed necessary and only part of spending by consumers is considered essential. Certainly an adequate standard of living must be maintained to sustain public morale and support for the war effort. However, excessive consumption of SCM-intensive goods is considered nonessential for stockpile purposes.

For most types of durable goods, 50 percent of consumer spending is considered nonessential. This percentage rises to 75 percent in the case of new cars. Most consumer spending on nondurable goods and services is considered essential, although 50 percent of gasoline purchases and 75 percent of foreign travel are considered nonessential.[95] Some two-thirds of new residential construction spending is treated as nonessential.

Homeland Recovery

The scenarios used in the process for determining stockpile requirements may include limited attacks on the U.S. homeland. To mitigate the hardships that result, spending to replace assets lost in such attacks, or used during the recovery period, is

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[94] Strictly speaking, exports are consumed overseas and are not part of essential U.S. civilian demand as such. In the DOD NDS requirements process, exports are adjusted in a separate step.

[95] Decrements for personal consumption amount to about 11 percent of projected spending and are concentrated mainly in consumer durables. Consumers are assumed to increase consumption of certain types of nondurable goods and services to compensate for reduced consumption of nonessential durable goods. Similar shifts in spending occurred during World War II. See Section E. of this Appendix for details on spending decrements.

considered essential.[96] This may include investment in production equipment and new construction by the private sector and the government as well as purchase of durable goods and housing by consumers.

C. Variations Using Current Structure: Reduce More, Reduce Less

The current approach to determining what should be considered essential still seems sensible from a conceptual point of view. However, the severity of the reductions for nonessential demand should be reaffirmed or changed. This section considers potential adjustments to make the reductions more severe or less severe.

The degree of austerity that should be imposed on the economy depends on circumstances during a contingency. How much is necessary to support the war effort and what civilian sacrifices are warranted? The national emergency scenarios specified for the DOD NDS requirements process present serious challenges but fall far short of repeating the scale and urgency of World War II. Thus the current approach calls for sacrifices but allows for the continued growth of the civilian economy. A stricter approach might require more sacrifices from the industrial sectors. A milder approach might call for less sacrifice by consumers.

It is also important to focus on the task at hand, namely determining inventory requirements for the National Defense Stockpile. The importance of preparing to support the national economy during a contingency must be weighed against the likelihood of that contingency, the cost of protective measures such as holding SCM inventories, and the urgency of other current claims on the Federal budget. There is thus ample room for judgment by the government on how to define essential civilian requirements for stockpile purposes.

1. Stricter Definition of Essential

One alternative approach would be to construe essential civilian demand narrowly, to include only what is necessary to support the war effort. Investment in productive equipment and new construction would be considered essential for industries closely linked to defense production but there would be much less support for other sectors or for the ongoing strength of the national economy.

- Overall, 30 to 50 percent of equipment investment would be deemed nonessential, compared to zero percent under the current approach.
- Decrements for new construction would be extended to the sectors that the current approach does not decrement, including the infrastructure sectors.

[96] For example, medical equipment might be destroyed by the attack or depreciated during the treatment of victims.

- Decrements to exports would be increased by up to ten percentage points from the current factors.
- A portion of government spending would be declared nonessential, as compared to all of it being essential under the present approach.
- The portion of spending on consumer durables that is deemed nonessential could be enlarged somewhat, although the existing decrements are already relatively severe.
- The spending decrements could be phased in more fully during the first year of the planning scenario.[97]

This stricter approach would have both positive and negative impacts.

- *Pro*: There would be a significant reduction in SCM requirements to support civilian spending on goods and services. Inventory requirements and costs would be reduced accordingly.[98]
- *Con*: Reduction in productive investment would damage the national economy, causing bottlenecks and limiting productivity growth. Defense production itself might be adversely affected, although the intent would be to allow sufficient essential investment to enable required defense production.
- *Con:* If this approach reduced stockpile requirements, it could lead to a more severe national shortage of SCMs during a contingency. During a severe national SCM shortage, the government would adjudicate between defense and civilian claims on available supplies. There is no guarantee that defense purposes would be fully satisfied under these circumstances, notwithstanding the existence of the National Defense Stockpile and the Defense Priorities and Allocations System.

2. More Relaxed Definition of Essential

Another alternative would be to view essential civilian demand more generously. The productive strength and growth of the economy would be given high priority and sacrifices in the standard of living would be reduced compared to the present approach.

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97 As noted above, the existing process decrements spending less during the first year than during subsequent years of the planning scenario.

98 In the current approach, decrements to spending on goods and services lead to reductions of 15 to 20 percent in requirements for SCMs. A stricter approach could reduce SCM requirements by 25 to 30 percent instead.

- The share of civilian durable goods consumption considered nonessential would be reduced. For example, the nonessential share for many spending categories could be cut from 50 percent under the current approach to 25 percent or less.
- The nonessential portion of new residential construction could be cut from 67 percent under the current method to 33 percent or less.
- For new construction investment in commercial sectors, the nonessential share could be reduced from 50 percent now to 25 percent or less.
- The nonessential share of exports could be reduced from the current range of 15 to 25 percent to 10 percent or less.
- The spending decrements could be phased in more gradually during the first year of the planning scenario.

Potential strengths and weaknesses of this approach include the following.

- *Pro*: There would be less disruption of the national economy and especially of the construction sector and the industries that require new construction.
- *Pro*: Consumers would enjoy an improved standard of living and would have less reason to question U.S. policy toward the contingency.
- *Con*: Requirements and costs for SCM inventories in the NDS could increase significantly.[99]
- *Con*: During a transition period, acquisitions for the stockpile might disrupt materials markets.

D. Alternative Structures for Specifying Essential Demand

The existing approach identifies a particular civilian spending pattern that is deemed essential for stockpile purposes. That pattern is used as an input to the process of determining SCM requirements and potential NDS inventories. However, even if DOD acquires and holds the requisite SCM inventories, there is no assurance that civilians will spend in the assumed way during an actual contingency. This section addresses how this disconnect affects the utility of the existing approach.

During a contingency, the government could institute processes to allocate materials among industries and to limit the purchase of nonessential goods and services. In this way, the government could ensure that the available SCMs were used for essential

[99] In the current approach, decrements to spending on goods and services lead to reductions of 15 to 20 percent in requirements for SCMs. A more generous approach could reduce SCM requirements by 5 to 10 percent instead.

purposes. However, allocation and rationing are fraught with difficulties, including market distortions and enforcement costs.

Instead, the government might allow market prices to allocate scarce materials among civilian sectors and users. In this case, the civilian spending pattern might be quite different from the pattern assumed for the stockpile study. To some extent, available SCM supply would be used to support spending defined here as nonessential. Rich users and industries would buy the products and SCMs they want, leaving some essential needs of others unfulfilled.

In practice, circumstances may force the government's hand. As shortages develop, it will become more difficult for manufacturers to fulfill contracts with priority ratings. The government may need to allocate SCMs to manufacturers to enable them to complete those contracts. Producers of nonessential goods will not receive allocations and may be forced to curtail production. Spending on nonessential goods that utilize SCMs will necessarily decline.[100]

Even if the detailed spending pattern developed under the current approach proves unenforceable, it serves as a useful indicator of the hardships and disruptions that the civilian sector would suffer. This explicit linkage is preferable to using some arbitrary definition of essential civilian needs that might unknowingly impose unacceptable disruptions. During an actual contingency, the government would determine whether intervention to correct the market outcome was warranted.

If the detail in the current approach is nevertheless considered irrelevant or misleading, more general alternative approaches could be devised. Three such approaches are described here, although they are not transparent about civilian hardships and disruptions and do not seem advisable.

1. Broader User Spending Categories

One approach would be to continue to focus on spending by civilians for goods and services, but define spending in very broad categories. For example, specify the share of total consumer durable goods spending that is nonessential rather than set such shares for twenty detailed types of durables as is done under the current approach. Similarly, collapse the thirty-one detailed construction categories used in the current approach to maybe three: industry, government, and consumers. To be useful, the categories should include mainly the goods and services that utilize SCMs rather than encompass all consumer or civilian spending.

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[100] Alternatively, producers may find inferior wartime substitutes for SCMs and continue producing their goods.

This approach would have advantages and disadvantages including the following.

- *Pro*: The specification of essential and nonessential spending would seem simpler and easier to communicate.
- *Con*: The specification would not convey much information about potential hardships and disruptions for the civilian economy. The nonessential shares might unknowingly imply unacceptable damage to the economy. To guard against this, those aggregate shares would need to be evaluated by studying detailed spending categories similar to those used in the current approach.
- *Con*: Applying a uniform reduction percentage to all spending in a larger group would necessitate a greater reduction in spending for many items to achieve the same overall reduction in SCM requirements as the current approach. This could be more disruptive.

2. User Requirements for SCMs

Another approach would similarly utilize several broad user groups but focus on their SCM requirements rather than their spending for goods and services. For example, a given percentage of consumer requirements for SCMs would be considered nonessential. Different percentages would be applied to industrial users, infrastructure providers, and the government. Of course, all defense requirements would remain essential. The reduction percentage would be applied uniformly to the value or quantity of each type of SCM required by a group. Variations of this approach could prioritize among types of SCM, setting different reduction percentages for each type or applying a single percentage to a weighted aggregate of SCM requirements.

Pros and cons for this approach include the following.

- *Pro*: The specification of essential and nonessential spending would seem simpler and easier to communicate. The impact on SCM requirements would be more transparent.
- *Pro*: This approach could ensure that the most expensive or problematic types of material would be decremented as much as or more than other types. However, some of the variations that could accomplish this might not seem simple
- *Con*: As noted for the previous alternative, this method would not reveal the hardships and disruptions that end users would face in meeting their requirements for goods and services. Special studies could be employed to assess and limit the disruptions, again complicating the approach.*Con*: In light of the previous objection, this approach lends itself to arbitrary manipulation of

SCM requirements without taking into account the resulting disruption of the U.S. economy.

3. Civilian Use of Defense Reserve

A rather extreme alternative would be to focus on defense requirements but include a reserve or safety margin when determining defense requirements for SCMs. The reserve would be available for meeting essential civilian demands if not needed for defense. The existence of essential civilian needs would be acknowledged but little or no attempt would be made to pre-judge those needs.

Strengths and weaknesses of this approach include the following.

- *Pro*: Focusing mainly on defense requirements might make sense if the government severely limited stockpile funding. This might result from tight defense budgets or from an expectation that the assumed national emergency was unlikely to occur.
- *Con*: Clearly, this approach would leave most civilian needs uncovered, including many that are considered essential under the current approach. Would this approach be sufficient to meet the statutory requirement?
- *Con*: In an actual emergency, the government might choose to allocate too much of the available SCM supply to essential civilian needs, leaving some defense needs unmet.
- *Con*: Under the current approach, any inventories held to meet essential civilian needs constitute an informal dual-purpose reserve that can be drawn on to meet defense needs that exceed projected levels. This cushion would be lost under the alternative described here.

E. Essential Civilian Demand Factors

This section contains a listing of percentage reductions in civilian demands to eliminate those demands considered nonessential. Section 14(b)(4) of the Strategic and Critical Materials Stock Piling Act requires that essential civilian requirements be included in the determination of NDS goals. DOD must thus identify civilian requirements that are essential and eliminate from consideration those that are nonessential. The adjustments which appear in Table B-2 on the following pages were specified by DOD after consultation with a civilian agency work group.[101] The

[101] Civil departments and agencies invited to participate in the essential civilian demand decision process included Agriculture, Commerce, Energy, Health and Human Services, Homeland Security, Housing

reductions in spending in the consumer categories indicated (mainly durable goods) are shifted to additional spending in other categories (selected non-durable goods and services) so that total Personal Consumption Expenditures (PCEs) remained at normal levels during the scenario.

Personal Consumption Expenditures (PCE)

Consumer spending is adjusted for all four years of the scenario. Spending for new automobiles, jewelry, boats/aircraft/recreational vehicles, and foreign travel is reduced 50 percent in the conflict year, and 75 percent in each of the three regeneration years (PCE categories 1, 14, 18, and 78). Spending on auto accessories (PCE category 5) is reduced by 15 percent during all four years. Spending for other consumer durables is reduced 25 percent, 50 percent, 50 percent, and 50 percent respectively for each of the four years. Examples include used cars, trucks, tires, appliances, furniture, and power tools (PCE categories 2-4, 6-13, 16, and 17). Spending on gasoline and oil (PCE category 27) is also reduced by 25 percent, 50 percent, 50 percent, and 50 percent. Consumer spending from these categories is permitted to shift to non-durable goods and services. Examples include clothing, medicine and motion picture theaters (PCE categories 23-26, 29-43, 47-51, 53-60, 62-63, and 66-77). The exceptions are categories such as food, alcohol, electricity, natural gas, and physicians (PCE categories 15, 19-22, 28, 44-46, 52, 61, and 64-65), which are held constant at their non-emergency levels.

Construction (CST)

Reductions are made to several construction categories. Residential investment (except mobile homes) is reduced 50 percent in the conflict year, and 67.5 percent in the three regeneration years (CST categories 1, 2, 4, and 31). Investment in selected nonresidential structures is reduced 25 percent in the conflict year and 50 percent in the three regeneration years. Examples include office buildings and hotels and motels (CST categories 5-9 and 12). Investment in other nonresidential structures remains at business-as-usual levels for each year. Examples include educational buildings, hospitals, electrical and gas utility facilities and farm service facilities (CST categories 3, 10-11, 13-30).

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and Urban Development, Interior, Labor, the Office of Management and Budget, State, Transportation, and Treasury.

Table B-2. Percentage Reductions in Civilian Demand to Eliminate Nonessential Spending[102]

Personal Consumption Expenditure Categories		Conflict Year	Regeneration Year 1	Regeneration Year 2	Regeneration Year 3
1	New Cars	50.0	75.0	75.0	75.0
2	Used Cars	25.0	50.0	50.0	50.0
3	New & Used Trucks	25.0	50.0	50.0	50.0
4	Tires & Tubes	25.0	50.0	50.0	50.0
5	Auto Accessories & Parts	15.0	15.0	15.0	15.0
6	Furniture, Mattresses, Bedsprings	25.0	50.0	50.0	50.0
7	Kitchen, Household Appliances	25.0	50.0	50.0	50.0
8	China, Glassware, Tableware, Utensils	25.0	50.0	50.0	50.0
9	Radio, TV, Records, Musical Instruments	25.0	50.0	50.0	50.0
10	Floor Coverings	25.0	50.0	50.0	50.0
11	Durable House furnishings	25.0	50.0	50.0	50.0
12	Writing Equipment	25.0	50.0	50.0	50.0
13	Hand Tools	25.0	50.0	50.0	50.0
14	Jewelry	50.0	75.0	75.0	75.0
15	Ophthalmic & Orthopedic Appliances	0.0	0.0	0.0	0.0
16	Books & Maps	25.0	50.0	50.0	50.0
17	Wheeled Goods & Durable Toys	25.0	50.0	50.0	50.0
18	Boats, Recreational Vehicles & Aircraft	50.0	75.0	75.0	75.0
19	Food, Off Premise	0.0	0.0	0.0	0.0
20	Food, On Premise	0.0	0.0	0.0	0.0
21	Alcohol, Off Premise	0.0	0.0	0.0	0.0
22	Alcohol, On Premise	0.0	0.0	0.0	0.0
23	Shoes & Footwear	+	+	+	+
24	Women's Clothing	+	+	+	+
25	Men's Clothing	+	+	+	+
26	Luggage	+	+	+	+
27	Gasoline & Oil	25.0	50.0	50.0	50.0
28	Fuel Oil & Coal	0.0	0.0	0.0	0.0
29	Tobacco	+	+	+	+
30	Semi-durable House furnishings	+	+	+	+

[102] The values (including zeroes) in the following tables represent the percentage decrements imposed to eliminate non-essential civilian items. For personal consumption expenditures, those categories with +'s are incremented proportionally so that total consumption across all the categories remains at the same level.

Table B-2. Percentage Reductions in Civilian Demand to Eliminate Nonessential Spending (Continued)

Personal Consumption Expenditure Categories		Conflict Year	Regeneration Year 1	Regeneration Year 2	Regeneration Year 3
31	Drug Preparations & Sundries	+	+	+	+
32	Toilet Articles & Preparations	+	+	+	+
33	Stationery & Writing Supplies	+	+	+	+
34	Non-durable Toys & Sport Supplies	+	+	+	+
35	Flowers, Seeds, Potted Plants	+	+	+	+
36	Cleaning Preparations	+	+	+	+
37	Lighting Supplies	+	+	+	+
38	Household Paper Products	+	+	+	+
39	Magazines & Newspapers	+	+	+	+
40	Other Non-durables	+	+	+	+
41	Owner Occupied Space Rent	+	+	+	+
42	Tenant Occupied Space Rent	+	+	+	+
43	Hotels, Motels	+	+	+	+
44	Other Housing	0.0	0.0	0.0	0.0
45	Electricity	0.0	0.0	0.0	0.0
46	Natural Gas	0.0	0.0	0.0	0.0
47	Water & Other Sanitary Services	+	+	+	+
48	Telephone & Telegraph	+	+	+	+
49	Domestic Services	+	+	+	+
50	Household Insurance	+	+	+	+
51	Other Household Operations: Repair	+	+	+	+
52	Postage	0.0	0.0	0.0	0.0
53	Auto Repair	+	+	+	+
54	Bridge, Tolls, etc.	+	+	+	+
55	Auto Insurance	+	+	+	+
56	Taxicabs	+	+	+	+
57	Local Public Transport	+	+	+	+
58	Intercity Railroad	+	+	+	+
59	Intercity Busses	+	+	+	+
60	Airlines	+	+	+	+
61	Travel Agents, Other Transportation Services	0.0	0.0	0.0	0.0
62	Laundries & Shoe Repair	+	+	+	+
63	Barbershops & Beauty Shops	+	+	+	+
64	Physicians	0.0	0.0	0.0	0.0
65	Dentists & Other Professional Services	0.0	0.0	0.0	0.0

Table B-2. Percentage Reductions in Civilian Demand to Eliminate Nonessential Spending (Continued)

Personal Consumption Expenditure Categories		Conflict Year	Regeneration Year 1	Regeneration Year 2	Regeneration Year 3
66	Private Hospitals & Sanitariums	+	+	+	+
67	Health Insurance	+	+	+	+
68	Brokerage & Investment Counselors	+	+	+	+
69	Bank Service Charges & Services	+	+	+	+
70	Life Insurance	+	+	+	+
71	Legal Services	+	+	+	+
72	Funeral Expenses, Other Personal Business	+	+	+	+
73	Radio & TV Repair	+	+	+	+
74	Movies, Theatre, Spectator Sports	+	+	+	+
75	Other Recreational Services	+	+	+	+
76	Education	+	+	+	+
77	Religious & Welfare Services	+	+	+	+
78	Foreign Travel	50.0	75.0	75.0	75.0

Table B-2. Percentage Reductions in Civilian Demand to Eliminate Nonessential Spending (Concluded)

Construction Categories		Conflict Year	Regeneration Year 1	Regeneration Year 2	Regeneration Year 3
1	1 Unit Residential Structures	50.0	67.5	67.5	67.5
2	2 Or More Unit Residential Structures	50.0	67.5	67.5	67.5
3	Mobile Homes	0.0	0.0	0.0	0.0
4	Additions & Alterations	50.0	67.5	67.5	67.5
5	Hotels, Motels, Dormitories	25.0	50.0	50.0	50.0
6	Industrial	25.0	50.0	50.0	50.0
7	Offices	25.0	50.0	50.0	50.0
8	Stores, Restaurants, Garages	25.0	50.0	50.0	50.0
9	Religious	25.0	50.0	50.0	50.0
10	Educational	0.0	0.0	0.0	0.0
11	Hospital & Institutional	0.0	0.0	0.0	0.0
12	Miscellaneous Nonresidential Buildings	25.0	50.0	50.0	50.0
13	Farm Buildings	0.0	0.0	0.0	0.0
14	Mining Exploration Shafts & Wells	0.0	0.0	0.0	0.0
15	Railroads	0.0	0.0	0.0	0.0
16	Telephone & Telegraph	0.0	0.0	0.0	0.0
17	Electric Light & Power	0.0	0.0	0.0	0.0
18	Gas & Petroleum Pipes	0.0	0.0	0.0	0.0
19	Other Structures	0.0	0.0	0.0	0.0
20	Highways & Streets	0.0	0.0	0.0	0.0
21	Military Facilities	0.0	0.0	0.0	0.0
22	Conservation	0.0	0.0	0.0	0.0
23	Sewer Systems	0.0	0.0	0.0	0.0
24	Water Supply Facilities	0.0	0.0	0.0	0.0
25	Residential (Public)	0.0	0.0	0.0	0.0
26	Industrial (Public)	0.0	0.0	0.0	0.0
27	Educational (Public)	0.0	0.0	0.0	0.0
28	Hospital (Public)	0.0	0.0	0.0	0.0
29	Other Buildings (Public)	0.0	0.0	0.0	0.0
30	Misc. Public Structures	0.0	0.0	0.0	0.0
31	Broker's Commission (Residential Structures)	50.0	67.5	67.5	67.5

F. Conclusion

The structure currently used to specify which civilian demands should be considered essential and nonessential seems sensible. In particular, it includes sufficient detail so that the potential hardships and disruptions caused by civilian austerity are transparent and can be kept within acceptable bounds. Whether the degree of austerity imposed using this structure is still appropriate is a matter for government judgment. Alternatives are outlined whereby the same structure could be used to specify austerity at levels that are either more or less severe than the current level.

Several alternative structures are also presented. These alternatives aid communication by simplifying the process. However, by operating at a higher level of aggregation, they make potential civilian hardships and disruptions less transparent.

For purposes of the upcoming 2011 DOD NDS requirements study, there is not a compelling reason to change the current approach. The Defense National Stockpile Center (DNSC) may nevertheless wish to solicit written comments on retaining this approach from the participants in the civilian agency working group. In the future, if new circumstances indicate major changes should be considered, it would be useful to conduct a workshop with those agencies.

Appendix C.
The “Proxy” Material Consumption Ratio (MCR) Method

Methodology for Computing Demand for Specialty and “New” Materials

This appendix describes the methodology used in the National Defense Stockpile studies to compute the demand for specialty and new materials.[103] The specialty materials demands are computed somewhat differently from the standard materials demands. The main reason for this is that Material Consumption Ratios (MCRs) are not available for the specialty materials, so an alternative methodology was needed. Historically, the specialty materials analysis started with detailed studies of specific materials; the demand computation methodology grew out of that.

Demands are computed for each combination of material, year of the scenario, and category (military or civilian). The demand computation can be divided into two parts, the basic procedure and the (optional) weapon-based demand. The basic procedure is performed for all specialty materials. For those materials where it is appropriate, a weapon-based demand can be added to the military demand computed by the basic procedure.

The first two sections below discuss the basic procedure; and some of its assumptions and properties. Included here are recent (Spring 2010) changes to the basic procedure that give the user some additional options. The third section pertains to the weapon-based demand. A mathematical description of the basic procedure appears in section 4.

1. General Description of Basic Procedure

The methodology starts with material consumption values (for each given material), based on historical data or projected estimates. There are two underlying scenarios, a “case” scenario[104] (for which material demands are computed) and a

[103] For the rest of this appendix, the term “specialty materials” will be used, with the understanding that the methodology also applies to the new materials.

[104] The case scenario might be the base case for the study or one of the sensitivity cases.

corresponding steady state scenario extending over the same time span. Traditionally, one material consumption value was input to the computational procedure. This value was based on the most recent year for which historical data were available; it was assumed to be the annual consumption for each year of the steady state scenario. There are now two additional options. First, estimated steady state consumption numbers for each year of the scenario can be given. Second, steady state consumption can be allowed to grow with the economy, consistent with the steady state industrial demands output by the FORCEMOB model (see below).

On hand are industry demands, determined by the FORCEMOB model.[105] [106] The outputs from two different FORCEMOB runs are used, one for the case scenario, the other for the corresponding steady state scenario.[107] Each set of FORCEMOB output contains dollar values of military and civilian industrial demand for each industry sector, for each year of the scenario. Together, the industry sectors span the entire economy.[108]

Each material is assumed to be used in a certain number of application areas. The annual amount of steady state material consumption in each application area is estimated by taking the total consumption value and apportioning it among the application areas (via judgmental inputs).

Each application area is associated with a subset of the industry sectors. (Often, this subset consists of just one industry.) The military/civilian split for each application area can be estimated from the military and civilian industrial demands computed by the steady state FORCEMOB run, averaging over the industries associated with that application (judgmental inputs can be used instead, if desired). The steady state military/civilian proportion depends on the application area. Traditionally, it was assumed to be the same for all years, but now there is an option to let it vary by year.

For each combination (in turn) of application area, category (military or civilian), and year, the material demand for the *case* scenario is computed by multiplying the corresponding steady state material demand value by a scenario adjustment factor, which represents the ratio of the case demand to steady state demand. Usually, these adjustment factors are derived from the FORCEMOB-generated industrial demands for the particular

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105 Note the distinction between material demand and industrial demand. The objective is to compute material demand; it is assumed that industrial demands are available.

106 The FORCEMOB output is not strictly necessary. It is used to determine adjustment and partitioning factors (see below). If desired, judgmental values for these factors can be used instead.

107 For the steady state scenario, no reductions of civilian demand for nonessential spending are applied, no import or export factors are used, the base military demand is not increased for homeland damage repair, the extraordinary military demand is set to zero, and the extraordinary investment demand is set to zero.

108 FORCEMOB computes extraordinary investment demand on industry, but this is not used in the specialty materials demand computation procedure.

industries to which the application area corresponds (see Section 4). However, judgmental values for the adjustment factors can be used instead.

For each year/category combination (for each material, in turn), the case material demands are summed over application area to yield a total value.

In summary, for each material:

1. Start with an annual amount (or amount for each year) of steady state material consumption. Partition this amount among application areas.
2. In each application area, partition the steady state consumption between civilian and military uses.
3. Apply adjustment factors to compute the case scenario demands from the steady state scenario demands.[109]
4. Sum the resultant amounts over application area to get total material consumption amounts, military and civilian, for the case scenario.
5. Repeat for each scenario year.
6. The partitioning fractions and adjustment factors can be computed via the industrial demands from FORCEMOB.

2. Discussion of Basic Procedure

Before the new options were added, the following assumptions were implicit in the procedure.

- During steady state, total consumption for each year of the scenario is unchanged and is equal to the annual consumption in the last year for which the IDA Study team can obtain historical data.
- During steady state, the split between military and civilian uses of a given application is the same for each year.

Together, these two assumptions imply that the estimated quantities of military and civilian material demand for each application are the same for each year of a steady state scenario. That is, neither steady state economic growth nor steady state changes in the patterns of civilian versus military uses have any impact on the forecast of material demands. Thus the material supply/demand mismatch problem that occurs when demand grows in accordance with the economy but supply remains more-or-less level is less

[109] The adjustment factor might be greater than or less than unity. Military demand would most likely be higher in the case scenario than in the steady-state scenario. But civilian demand might well be less, if the case scenario includes only the civilian demand that is deemed essential.

likely to occur. (This problem has occurred with the data used for the standard materials analysis; see the discussion in recent Reports to the Congress.)

However, the new options can relax these assumptions, allowing steady state consumption to grow with the economy or to be set to input estimated amounts. The military-civilian split can also vary by year, based on the steady-state FORCEMOB military and civilian industrial demands, which vary by year.

The military and civilian adjustment factors (usually computed from the FORCEMOB forecast industrial demand) represent the relative change in demand comparing the case scenario to the steady state scenario. For example, if the industrial demand in 2001 is 20 percent higher in the case scenario than in the steady state scenario, then the estimated material demand will also be 20 percent higher. Different ratios can be computed for different years of the scenario. This connection between materials, application areas, and industries makes it possible to develop a computational procedure in which changes in industry demand lead to changes in material demand. Such a procedure is similiar, in concept, though not detail, to the MCR computation – hence the term "proxy MCR approach."

3. Addition of Weapon-Based Demand

Some of the specialty materials have uses in specific weapon systems. For example, germanium is used in infrared sensor systems. The rather aggregated military demand computation described above might not completely encompass this special-purpose source of material requirement. For such materials, if desired, the overall military demand as computed above can be incremented by a weapon-specific demand. The weapon-specific demand is computed by:

- Taking the numbers of weapons (major end items) in the case scenario weapon requirements package that use the material,
- Multiplying by (input) factors that give the amount of material used per weapon,
- Summing over weapon type to yield an overall total material demand, and
- Dividing the overall total by the number of years in the scenario to yield an annual demand amount, which is added to each year's military demand.

There is a potential for double counting here, because high conflict military demand can lead to a high military scenario adjustment factor. Note, however, that double counting demand is a conservative assumption when determining material shortfalls.

4. Mathematical Description of Basic Procedure

A mathematical description of the basic procedure follows. Consider one specific material (the process is repeated for each material, in turn). Define the following variables.

n = number of application areas for the material in question

J = number of industry sectors

t_0 = a base year for the analysis, often the first year of the scenario. If one (historical) consumption value is given and the economic growth option is exercised, t_0 should be the year of that consumption value.

C_t = total steady state material consumption in year t of the scenario, in the latest consumption analysis. These values can be input, or the economic growth option can be invoked to compute the C_t from the steady state consumption for a base year, or a single value can be used for all years (the traditional approach).

η_i = proportion of the total steady state material consumption that is in application area i (i=1,…,n). This is an input.

q_{it} = total steady state material consumption in application area i: in year t: $q_{it} = \eta_i C_t$ (i=1,…,n).

S_i = the set of all industries that correspond to application area i (i=1,…,n). (Frequently, the set S_i contains only one industry. But the same industry might be associated with several different application areas.) These values are inputs.

$x_j^m(t)$ = the steady state military demand in industry j in year t of the scenario (j=1,…,J). (This and the following three quantities are all obtained from FORCEMOB.)

$x_j^c(t)$ = the steady state civilian demand in industry j in year t of the scenario
(j=1,…, J).

$\hat{x}_j^m(t)$ = the case military demand in industry j in year t of the scenario (j=1,…, J).

$\hat{x}_j^c(t)$ = the case civilian demand in industry j in year t of the scenario (j=1,…, J).

μ_{it} = proportion of steady state material consumption in application area i in year t that is for military purposes (then proportion (1–μ_{it}) is for civilian purposes). If this value is input, rather than being computed from the FORCEMOB results, the same value must be used for each year.

$\varphi_i^m(t)$ = the adjustment factor for military demand in application area i in year t of the case scenario (i=1,…,n).

$\varphi_i^c(t)$ = the adjustment factor for civilian demand in application area i in year t of the case scenario (i=1,…,n).

We wish to compute:

$\hat{q}_i^m(t)$ = the estimated military material demand for application i in year t of the case scenario (i=1,…,n) and

$\hat{q}_i^c(t)$ = the estimated civilian material demand for application i in year t of the case scenario (i=1,…,n).

These quantities are computed by the equations:

$$\hat{q}_i^m(t) = q_{it}\mu_{it}\varphi_i^m(t) \ ,$$

$$\hat{q}_i^c(t) = q_{it}(1-\mu_{it})\varphi_i^c(t) \ .$$

Often (but not always; values can simply be input) the terms μ_{it}, $\varphi_i^m(t)$, and $\varphi_i^c(t)$ are computed from the FORCEMOB results, as follows:

$$\mu_{it} = \frac{\sum_{j \in S_i} x_j^m(t)}{\sum_{j \in S_i} x_j^m(t) + \sum_{j \in S_i} x_j^c(t)}$$

$$\varphi_i^m(t) = \frac{\sum_{j \in S_i} \hat{x}_j^m(t)}{\sum_{j \in S_i} x_j^m(t)}$$

$$\varphi_i^c(t) = \frac{\sum_{j \in S_i} \hat{x}_j^c(t)}{\sum_{j \in S_i} x_j^c(t)}$$

If the economic growth option is being exercised, the adjustment factors take into account both steady state economic growth and case vs. steady state adjustments in a single step. Namely, the following formulas are used.

$$\varphi_i^m(t) = \frac{\sum_{j \in S_i} \hat{x}_j^m(t)}{\sum_{j \in S_i} x_j^m(t_0)}$$

$$\varphi_i^c(t) = \frac{\sum_{j \in S_i} \hat{x}_j^c(t)}{\sum_{j \in S_i} x_j^c(t_0)}$$

It is also possible (user option) to have μ_{it} not vary by year, by setting, for each t,

$$\mu_{it} = \frac{\sum_{j \in S_i} x_j^m(t_0)}{\sum_{j \in S_i} x_j^m(t_0) + \sum_{j \in S_i} x_j^c(t_0)}$$

However the factors μ_{it} , $\varphi_i^m(t)$, and $\varphi_i^c(t)$ are set, the total case scenario military demand (for the given material) in year *t* is then

$$Q^m(t) = \sum_{i=1}^{n} \hat{q}_i^m(t) \ ,$$

and the total case scenario civilian demand in year *t* is

$$Q^c(t) = \sum_{i=1}^{n} \hat{q}_i^c(t) \ .$$

Appendix D.
Country Reliability Protocols

The Defense Intelligence Agency (DIA) was provided with a list of questions (see Table D-1) to perform their country reliability evaluations for the 2011 National Defense Stockpile (NDS) requirements analysis. DIA’s Defense Resource Industry office, Defense Industry Division, has regional materials experts that have been performing this assessment for the Defense National Stockpile Center for many years. Their office considers approximately 175 countries aggregated into four regions. They monitor and track materials issues on an ongoing basis. In addition, the regional offices collaborate with each other to ensure that assessments are consistent and properly account for any latest developments.

Table D-1. Questions Posed to DIA Concerning Country Reliability

Question 1: Ability to Supply During Base Case Conflict Scenario

Please assess—in the context of the Base Case NDS conflict scenario (description attached)—the likely degradation in country X's ability to supply strategic and critical materials (S&CMs) to world markets. (A list of countries and the S&CMs they provide appears in a separate file.)

Please use a scale of 0-100%, with 100% meaning fully able (no degradation) and 0 meaning totally unable (complete degradation).

Ignore *direct* wartime damage (e.g., bombing damage) in your estimates. Consider other factors likely to affect supply during a Base Case scenario, e.g., power shortages, transportation breakdowns, labor strife, civil unrest, or *indirect* effects of Base Case conflicts.

Distinguish between year 1 (the conflict year) and years 2-4 (the three regeneration years). If you wish to input different values for the various regeneration years, please do so.

Question 2: Willingness to Sell to U.S. During Base Case Conflict Scenario

Please also assess—in the context of the same Base Case NDS conflict scenario—the extent of willingness of country X to sell S&CMs to the *United States*.

Please use a scale of 0-100%, with 100% meaning fully willing and 0 meaning totally unwilling.

This question asks specifically about anti-*U.S.* sentiment and orientation.

Distinguish between year 1 (the conflict year) and years 2-4 (the three regeneration years). If you wish to input different values for the various regeneration years, please do so.

Question 3: General Reliability (Ability/Willingness) in Near-Term Ongoing Environment

Please assess the general reliability (ability/willingness) of country X to supply S&CMs to the United States over the next 2-3 years—in the context of the conditions you believe most likely to prevail (as opposed to the Base Case conflict scenario). Consider factors such as those mentioned in Questions 1 and 2, and also economic and market factors.

Please use a scale of 0-100%, with 100% meaning fully able and willing to sell to the U.S. and 0 meaning totally unable or unwilling. For Question 3, one value encompasses both ability and willingness.

Your Explanations Are Welcome

You are invited (but certainly not required) to provide explanatory notes regarding any factors that influenced your determination of country ability or willingness. Insert comments in the cells of the response spreadsheet or put comments on an additional worksheet or file.

Appendix E.
Abbreviations

Av Oz	Avoirdupois Ounce (28.350 Grams)
ATI	Allegheny Technologies Inc.
B_2O_3	Boron Oxide
C	Carbon
CAPE	Cost Analysis and Program Evaluation (DOD)
CARD	Cost Analysis and Research Division (IDA)
Cb	Columbium (Niobium)
CC	Conventional Conflict
CEA	Council of Economic Advisors
CIA	Central Intelligence Agency
Co	Cobalt
CONUS	Continental United States
CRT	Cathode Ray Tube
CST	Construction
DCMA	Defense Contract Management Agency
DIA	Defense Intelligence Agency
DLA	Defense Logistics Agency
DNSC	Defense National Stockpile Center
DOC	Department of Commerce
DOD	Department of Defense
DPA	Defense Production Act
DPAS	Defense Priorities and Allocations System
EOC	Emergency Operating Capacity
FEMA	Federal Emergency Management Agency
FL	Flasks (76 Pounds)
FORCEMOB	Forces Mobilization Model
FYDP	Future Years Defense Program

GDP	Gross Domestic Product
GFM	Government Furnished Material
HHA	High Hard Armor
IA	Infrastructure Availability
IBC1	Interim Base Case 1
ICBM	Intercontinental Ballistic Missile
IDA	Institute for Defense Analyses
IED	Improvised Explosive Device
ILIAD	Interindustry Large-scale Integrated and Dynamic Model
ILM	Industry-Level Module
INFORUM	Interindustry Forecasting at the University of Maryland
JIMPP	Joint Industrial Mobilization Planning Process
JROC	Joint Requirements Oversight Council
JS	Joint Staff
$K	Thousands of dollars
KG	Kilograms
LB	Pounds
LB Cb	Pounds of Contained Columbium
LB Co	Pounds of Contained Cobalt
LB Ta	Pounds of Contained Tantalum
LB W	Pounds of Contained Tungsten
LCT	Long Calcined Tons
LDT	Long Dry Tons
LIFT	Long-term Interindustry Forecasting Tool
LME	London Metals Exchange
LT	Long Tons
$M	Millions of dollars
MCR	Material Consumption Ratio
MDA	Missile Defense Agency
MRAP	Mine-resistant ambush-protected
MS	Market Share
Msi	Millions of pounds per square inch

MT	Metric Tons
MT Y_2O_3	Metric Tons of Yttrium Oxide
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NDS	National Defense Stockpile
Ni	Nickel
NSE	National Security Emergency
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OSD	Office of the Secretary of Defense
PA&E	Program Analysis and Evaluation (OSD)
PAN	Polyacrylonitrile
Pb	Lead
PCE	Personal Consumption Expenditures
PGM	Platinum Group Metal
PRC	Peoples' Republic of China
Q&T	Quenched & Tempered
QDR	Quadrennial Defense Review
REO	Rare Earth Oxide
RF	Reliability Factor
RHA	Rolled Homogeneous Armor
S&CM, SCM	Strategic and Critical Material
SDT	Short Dry Tons
Si	Silicon
SIC	Standard Industrial Classification
SL	Shipping Loss
SME	Subject Matter Expert
SMSP	Strategic Materials Security Program
SPC	Survey of Plant Capacity (U.S. Department of Commerce)
SSM	Stockpile Sizing Model
ST	Short Tons
ST V	Short Tons of Contained Vanadium

Ta	Tantalum
Tr Oz	Troy Ounces
UFP	Usable Foreign Production
UN	United Nations
USG	United States Government
USGS	U.S. Geological Survey (Department of the Interior)
V	Vanadium
VAR	Vacuum Arc Re-melt
VIM	Vacuum Induction Melt
VLM	Vendor-Level Module
W	Tungsten
WD	War Damage
WPB	War Production Board
Y_2O_3	Yttrium Oxide

Appendix F.
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Appendix G.
Illustrations

Figures

Tables

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13. SUPPLEMENTARY NOTES

14. Abstract

In 1987, the U.S. Congress assigned the Secretary of Defense the job of determining requirements for and managing the National Defense Stockpile (NDS) of "strategic and critical" non-fuel materials (S&CMs). Since then, the Institute for Defense Analyses (IDA) has provided regular analytic support to the Department of Defense (DOD) in structuring and implementing a stockpile requirements assessment process. This paper summarizes IDA's latest analytic support to the DOD and the Defense National Stockpile Center (DNSC) in the NDS program area, including analyses to support DOD's ongoing transition from an NDS to a Strategic Materials Security Program (SMSP).

15. SUBJECT TERMS

National Defense Stockpile, NDS, Strategic Materials Security Program, SMSP, Defense National Stockpile Center, DNSC, strategic and critical non-fuel materials, S&CMs, critical materials, rare earths, high-performance carbon fibers, beryllium, lithium, risk management, risk mitigation, supply-chain, defense industrial base, import-dependence, foreign-dependence, purchasing efficiencies, Stockpiling Act, NDS requirements process, essential civilian requirements, industrial base modeling, national security emergency scenario, inter-agency decision-support processes

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